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COLD LAKE - BEAVER RIVER WATER MANAGEMENT STUDY

VOLUME 3
WITHDRAWAL DEMAND AND ASSESSMENT

Appendix D . . . Withdrawal Water Demands
Appendix E . . . . Water Balance Model

Water Resources

Alberta

ENVIRONMENT
Planning Division

INDEX OF VOLUMES

1. MAIN REPORT

2. WATER SUPPLY
   - Appendix A - Surface Water Resources
   - Appendix B - Ground Water Resources
   - Appendix C - Ground Water Modelling

3. **WITHDRAWAL DEMAND AND ASSESSMENT**
   - **Appendix D - Withdrawal Water Demands**
   - **Appendix E - Water Balance Model**

4. FISHERIES
   - Appendix F - Fisheries Studies; Main Report
   - Appendix G - Fisheries Studies; Detailed Data Report

5. FISHERIES AND WILDLIFE
   - Appendix H - Fish and Fisheries; Status and Utilization
   - Appendix I - Water Related Wildlife Resources

6. RECREATION
   - Appendix J - Water Based Recreation

7. ECOLOGICAL INVENTORY OF LAKE SHORELINES
   - Appendix K - Ecological Inventory of Lake Shorelines; Summary
   - Appendix L - Ecological Inventory of Lake Shorelines; Detailed Report

8. WATER QUALITY
   - Appendix M - Lake Trophic Assessment
   - Appendix N - Impacts of Lake Level Fluctuations on Trophic Status
   - Appendix O - River Water Quality Assessment

COLD LAKE — BEAVER RIVER
WATER MANAGEMENT STUDY

VOLUME 3
WITHDRAWAL DEMAND AND ASSESSMENT

PREPARED BY
PLANNING DIVISION
ALBERTA ENVIRONMENT
December 1983

Submitted to: Hon. F. Bradley
Minister of Environment

APPENDIX D

WITHDRAWAL WATER DEMANDS

A Report Prepared By
MACLAREN PLANSEARCH : LAVALIN

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07 December 1981

Mr. Ron Hicks
Athabasca River Basin Planner
Planning Division
Alberta Environment
9820 106 Street
Edmonton, Alberta
T5K 2J6

Withdrawal Water Demands
Cold-Lake Beaver River Basin

Dear Mr. Hicks:

We are pleased to submit our report on water demand in the Beaver River Basin. The main report of the study was to qualify current and future withdrawal water demands and return flows for various industrial scenarios.

We hope this report meets with your approval and that the data contained in the report will be useful in your framework planning.

Yours very truly,

MACLAREN PLANSEARCH SERVICES LTD.

Jacques Penel, P.Eng.
Project Manager

JP/dl

encl.

ABSTRACT

Alberta Environment is developing a framework plan for long-term management of water resources in the Beaver River basin. Water use is expected to increase more rapidly than current growth rates due to development of in-situ heavy oil extraction plants. Municipal demands are also expected to increase as a result of industrial development and natural population increases.

The purpose of the study was to quantify withdrawal water demands for the Beaver River basin. The water quantity demands were designed as input to a water balance model. Current and future withdrawal and return flows were quantified by examining water licences and annual reports, and interviewing government and industry representatives. Industrial development scenarios were identified for the years 1985, 2000 and 2015 and all water demands were quantified for those years. The impacts of water shortages were discussed for each use.

In addition, water quality criteria and requirements for government, industry, and municipalities were defined for use as input to water quality modelling done as part of the framework plan.

TABLE OF CONTENTS

Page

Acknowledgements i

Abstract ii

List of Tables v

List of Figures vi

1.0 INTRODUCTION 1-1

- 1.1 Purpose 1-1
- 1.2 Approach 1-4

2.0 LEGAL ARRANGEMENTS 2-1

- 2.1 Master Agreement on Apportionment 2-1
- 2.2 Alberta Water Resources Act 2-3

3.0 WATER USES 3-1

- 3.1 Domestic 3-4
- 3.2 Municipal 3-4
  - 3.2.1 Ardmore - Fort Kent 3-5
  - 3.2.2 Bonnyville 3-5
  - 3.2.3 Cold Lake - Grand Centre - CFB Cold Lake 3-6
  - 3.2.4 Glendon 3-7
  - 3.2.5 Indian Reserves 3-8
  - 3.2.6 Mallaig 3-10
  - 3.2.7 Others 3-10
- 3.3 Irrigation 3-10
- 3.4 Industrial 3-10
  - 3.4.1 Oil Recovery Processes 3-11
  - 3.4.2 Water Requirements for Oil Recovery 3-13
- 3.5 Other 3-18
- 3.6 Non-Consumptive Uses 3-18

Page

4.0 CURRENT WATER DEMANDS 4-1

4.1 Water Quantity Demands 4-1

4.1.1 Authorized Demands by Reach 4-3
4.1.2 Authorized Demands by Purpose 4-5
4.1.3 Unlicenced Demands 4-10
4.1.4 Seasonal Demands 4-11

4.2 Water Quality Criteria 4-16

5.0 FUTURE WATER DEMANDS 5-1

5.1 Industrial Development Scenarios 5-1

5.2 Population Projections 5-5

5.3 Water Quantity Demands 5-8

5.3.1 Domestic and Municipal 5-8
5.3.2 Irrigation 5-12
5.3.3 Industrial 5-12
5.3.4 Other 5-16
5.3.5 Non-Consumptive Uses 5-16

6.0 EFFECTS OF WATER SHORTAGE 6-1

7.0 CONCLUSIONS 7-1

8.0 REFERENCES 8-1

Appendix A: Active Licenced Water Projects in the Beaver River Basin

Appendix B: Active Licenced Water Projects Within Designated Reaches

Appendix C: Water Quality Criteria

Appendix D: Future Domestic and Municipal Water Withdrawals and Returns

Appendix E: Current and Future Oil Company Water Withdrawals and Returns

Appendix F: Potential and Proposed Ducks Unlimited Projects in the Beaver River Basin

LIST OF TABLES

		Page
3.1	Population, Beaver River Basin	3-2
4.1	Summary of Licenced Water Withdrawals and Returns by Reach	4-6, 7,8
4.2	Summary of Licenced Water Withdrawals and Returns by Purpose	4-9
4.3	Unlicenced Water Demands, Beaver River Basin, 1980	4-12
4.4	1980 Monthly Municipal Water Demands	4-14
5.1	Current and Projected Heavy Oil Production - Beaver River basin (m^3/day)	5-3
5.2	Low Population Projections - Beaver River Basin	5-9
5.3	High Population Projections - Beaver River Basin	5-10
5.4	Summary of Future Domestic and Municipal Water Withdrawals and Returns	5-11
5.5	Oil Company Water Withdrawals and Returns - 1985	5-13
5.6	Oil Company Water Withdrawals and Returns - 2000	5-14
5.7	Oil Company Water Withdrawals and Returns - 2015	5-15
7.1	Summary of Current and Future Water Withdrawals and Returns by Purpose - Beaver River Basin	7-3

LIST OF FIGURES

Page

1.1 Beaver River Basin 1-2

3.1 Municipalities and Population Centres 3-3

3.2 Current and Future Oil Sands Projects 3-12

3.3 Steam Injection Flow Diagram with Water Recycling 3-15

4.1 Cold Lake - Beaver River Basin Water Balance Model Schematic 4-4

5.1 Future Oil Production versus Population Increase Cold Lake Area 5-7

7.1 Current and Future Water Withdrawals and Returns - Beaver River Basin 7-4

INTRODUCTION

1.0 INTRODUCTION

1.1 Purpose

The Beaver River is a relatively small river that rises in northeastern Alberta near Lac La Biche and flows into Saskatchewan near Cold Lake. It has a mean annual total discharge of 860,000 dam^3/yr. The basin lies in the headwater of the Churchill River System, the only river in Alberta to do so. The basin is 22,000 km^2 in area, and straddles the Alberta-Saskatchewan border (See Figure 1.1).

Water use is becoming an important issue in the Cold Lake - Beaver River Basin as a result of proposed commercial heavy oil extraction plants. Combined with the associated population growth, increased economic activity and recreational use, demands will be placed on the water resources of the basin. In order to facilitate orderly management of the anticipated demands, Alberta Environment is developing a framework plan for the long-term management of water resources in the Cold Lake - Beaver River Basin.

Alberta Environment has developed a multi-component study that will address the issues of the Cold Lake - Beaber River Water Management Plan. This report covers the Withdrawal Water Demands part of the Water Use Component.

The objectives of this study, as outlined in the study Terms of Reference were to determine the water demand associated with each category of withdrawal water use as follows:

- define current water use including compiling and analysing use data, determining any seasonal and annual variations and determining any factors which may affect use data or efficiency.
- forecast potential development and population growth within and adjacent to the study area for the short (1985), medium (2000) and long (2015) term and define alternative development scenarios for each time frame.
- determine withdrawal and return flow quantity and quality for each alternative development scenario.
- define the physical characteristics of the existing and future water use system including withdrawal and return points and storage and treatment requirements.
- determine the effects of water shortages on the existing and future water use systems.

1.2 Approach

Data from this report was intended for use in two other components of the Cold Lake-Beaver River Study: the water balance and the water quality components. Both components involve use of computer models that simulate effects of changes in the quantity or quality of withdrawals and returns on reaches or sub-basins or the Beaver River Basin. Data developed was intended for that purpose.

For the purposes of this study, withdrawal is defined as the gross water diversion from the source. Return flow is the water returned to the source after use. The difference between the withdrawal and return is the water consumed, or lost from the system during use.

The degree of water treatment used by each municipality, and the water quality criteria applicable to municipal and industrial users was collected as information for the water quality modelling process. Although withdrawals and returns generally require water treatment, the overall effect on increased water use and re-use will be evaluated by the model.

The general design of municipal water use systems was described with respect to water supply, storage and waste treatment. The Municipal Engineering Branch of Alberta Environment, Town Managers and Engineers, and Canadian Indian and Northern Affairs were approached to provide data on existing and planned systems.

The use of water by the petroleum industry for heavy oil extraction process is a major forecasted demand in the basin. A flow diagram showing the process was developed and the various methods of extraction (steam stimulation, steam drive, and insitu burning) were described. Interviews were held; published reports and questionnaires were consulted. In order to estimate amounts of water used, some assumptions were necessary. These assumptions regarding the water cycle during the oil extraction process were derived by MacLaren Plansearch staff with assistance from Alberta Environment based on discussions with industry representatives.

Current water demands were quantified using data from government agencies and officials, and from oil company representatives. A computer print-out of water licences was used as a base. Data from the licences were verified by checking each file, checking annual reports associated with some files, and by verifying data with government and industry officials. Current demands that do not require a licence were estimated from population figures and water use coefficients. Demands imposed as a result of limits imposed by the apportionment agreement was discussed generally as these limits become significant during periods when net withdrawals are high. The seasonality of each demand was discussed in view of the data requirements of the water balance model.

The amount of industrial development that could occur within the basin was evaluated by identifying a low and a high development scenario for each of three years - 1985, 2000 and 2015. This was accomplished by discussing future plans with each oil company holding leases in the Cold Lake area. Using a combination of data from the oil companies and from the water use cycle derived for this study, future development was assessed both in terms of oil production and water use. This data formed the basis for the population projections for the basin, and for domestic and municipal water demands in the future.

The population projections were derived using data from Alberta Municipal Affairs (1979). A relationship was found between oil production and population increase. This relationship was used to estimate population increases that accompany the economic development associated with oil development for various scenarios. Additional population increases due to natural growth were also evaluated using revised government data extended to 2015.

Domestic and municipal future water demands were based on the population projections, after the population increases had been distributed among towns as forecasted by Alberta Muncipal Affairs (1978). The data were calculated for each development scenario and presented for each town with withdrawal and return locations and reach numbers noted.

Finally, the effects of possible future water shortages was discussed. The water balance model will require the assignment of penalty values (arbitrarily) to ranges of water use for each purpose. The penalty system allocates a scarce resource between contending users at various levels of withdrawal. This approach is intended to assess the effect of water shortages on the individual user and on the water system as a whole. The discussion in this report was intended to be used as guidance for the assignment of penalty values.

All data in this report are presented in metric units. Water quantities are generally presented in dam^3/yr. One dam^3 is equal to one cubic decameter or 1000 cubic meters.

LEGAL ARRANGEMENTS

2.0 LEGAL ARRANGEMENTS

Two legal arrangements have a bearing on water demands within the basin. The Master Agreement on Apportionment (Canada, P.C.. 1969) governs demands made by the Province of Saskatchewan over surface water that originates in Alberta; and the Alberta Water Resources Act (Alberta, 1980) governs the priority of surface water and groundwater licences within the river basins of Alberta.

2.1 Master Agreement on Apportionment

Under the Master Agreement on Apportionment, Alberta made commitments to the Province of Saskatchewan regarding the quantity of flow that must be allowed to cross the border. Section 3 of Schedule A states that:

> "3. Alberta shall permit a quantity of water equal to one-half the natural flow of each watercourse to flow into the Province of Saskatchewan, and the actual flow shall be adjusted from time to time on an equitable basis during each calendar year, but this shall not restrict or prohibit Alberta from diverting or consuming any quantity of water from any watercourse provided that Alberta diverts water to which it is entitled of comparable quality from other streams or rivers into such watercourse to meet its commitments to Saskatchewan with respect to each watercourse. "

This allows large diversions out of one tributary of the Beaver River as long as the amount is made up with flows from another tributary of comparable quality.

The Water Survey of Canada (Environment Canada, 1981) considers the Beaver River to be natural flow, thus no adjustments of flows are required to calculate Saskatchewan's entitlement. The mean of annual total discharges for the river is 860,000 dam^3 (1956-1979 records, Beaver River at Cold Lake Reserve Station Number 06AD006).

Based on the available record, Saskatchewan is entitled to an average annual flow of 430,000 dam^3. Yearly total discharges have varied from 241,000 dam^3 in 1968 to 1,920,000 dam^3 in 1962. The Prairie Provinces Water Board is responsible for monitoring and reporting on apportionment of waters (Canada, P.C., 1969).

2.2 Alberta Water Resources Act

In Alberta, authority is required for all surface and groundwater withdrawals under the Water Resources Act (Alberta, 1980).

To preclude the necessity for the issue of indiviual licences for minor domestic use, the Act provides (Section 4) that the owner or occupant of land may use such quantity of surface or groundwater as he requires for domestic purposes on the land. In the exercise of the right, a person may pump or otherwise convey water for domestic purposes to fill and tank, cistern, trough or a small dugout or install a well without a permit, interim licence or licence.

There are two orders of priority established in the Act: the first is an order in time, and the second is an order of preference of use. The priority in time is established by the date of filing of an acceptable application and plan and appears as the "unique number" on a licence. The priority of use is established by the Act and recognizes the following order: domestic, municipal, irrigation and other agricultural, industrial, water power and other purposes. Section 11, subsections (1) through (3) details the system:

(1) Upon application being made therefore as provided in this Act and the regulations, a person may acquire, subject to any valid and subsisting rights,

(a) a licence to divert and use water for any or all of the following purposes:

- (i) domestic purposes;
- (ii) municipal purposes;
- (iii) irrigation and other agricultural purposes;
- (iv) industrial purposes;
- (v) water power purposes;
- (vi) other like purposes;

(b) a licence to impound water for the purpose of water management, flood control, erosion control, flow regulation, conservation, recreation or the propagation of fish or wildlife or for any like purpose, or

(c) a licence to use water in its natural state for the purpose of conservation, recreation or the propagation of fish or wildlife or for any like purpose, or

(d) a licence to divert water, otherwise than by impoundment or storage, for the purpose of water management, flood control, drainage, erosion control or channel re-alignment or for any like purpose, or

(e) a permit

- (i) to lay, place, build or erect in, over, under, upon or adjacent to any water any structure, device, contrivance or thing, or any earth, sand, gravel, or other material, which will interfere with or will be capable of interfering with the present or future development, conservation or management of that water, or
- (ii) to remove or disturb any earth, sand, gravel or other material forming part of the bed, shore or banks of any water, where the removal or disturbance will interfere with or will be capable of interfering with the present or future development, conservation or management of water.

(2) Applications for Licences or permits under subsection (1) have priority as between themselves according to the dates of their filing with the Minister, and they shall be numbered consecutively in the order in which they are filed.

(3) Where two or more applications for licences under subsection (1) for water from a common source are filed on the same date, they shall be assigned priority as between themselves in accordance with the purposes for which a licence may be acquired are set forth in subsection (1).

The principle of priority of use provides that a user of higher preference may apply for the cancellation of a right held by a user of lower preference and, upon payment of compensation, may acquire both the water and the priority in time held by the less preferred user. These provisions are found in Section 11, Subsections (4) through (7).

> 11. (4) Where a person requires water from a common source for a purpose that in the order in which purposes for which a licence may be acquired are set forth in subsection (1) precedes the purpose for which water from that source has been allocated under an interim licence or licence, that person may apply to the Minister
>
> (a) to have that interim licence or licence cancelled, in whole or in part, to the extent necessary to meet his requirements, and
>
> (b) for a licence for his purpose having the same priority as that interim licence or licence.
>
> (5) Where the Minister approves an application under subsection (4), the interim licence or licence may be cancelled in whole or in part as the Minister considers proper, and the applicant may be issued a licence under subsection (1) for his purpose in accordance with his application and, notwithstanding section 37, subsection (1), such licence shall have the same priority as the wholly or partly cancelled interim licence or licence.
>
> (6) The holder of the interim licence or licence that has been cancelled in whole or in part under subsection (5) and any person who lawfully obtained water from the holder are entitled to be paid compensation by the applicant for any loss or damage sustained by him or them as a result of the cancellation, in whole or in part of the interim licence or licence.
>
> (7) Where the applicant and the parties described in subsection (6) are unable to agree as to the compensation payable, the compensation payable shall be determined in such a manner as the Minister may authorize.

The rights of licensees with priority in time have been enforced on numerous occasions however, the provisions of Section 11 pertaining to priority of use have not been exercised. Hence, priority of use to date, at least, is of theoretical or potential rather than practical significance.

Under Section 12, the Lieutenant Governor in Council may reserve any unappropriated water in order to determine how to use the water to the best advantage. He may thereafter authorize the allocation of the reserved water as he deems best in the public interest. This provision may circumvent an emergency concerning the water usage. If a declared emergency does occur, however, under Section 13, the Lieutenant Governor in Council may suspend the rights of licences and re-allocate the water to meet the needs of the emergency. This provision is in harmony with declared government policy first for human consumption, next for food production, then for industrial use and finally for other purposes.

WATER USES

3.0 WATER USES

Water is used for seven purposes within the Beaver River Basin: domestic, municipal, irrigation, industrial, "other", storage, and diversion. Storage and diversion uses are grouped here under non-consumptive uses.

Domestic and municipal systems are sized for the population served. Table 3.1 lists past and current populations within the basin while Figure 3.1 shows their location. Approximately 36 percent of the population is urban. This urban population has increased relatively rapidly from 7293 to 9465 people from 1976-1980. The rural population has not increased as rapidly: only from 9848 to 10,482 people from 1976-1980 in the Municipal District of Bonnyville. Cold Lake and Grand Centre have formed a Regional Utilities Board that is presently improving their system. Bonnyville is also improving its system for the anticipated population increase.

Irrigation systems are small and relatively insignificant. Pasture improvement and grain crops are the major agricultural activities.

Industrial water use systems in the basin are almost exclusively for in-situ oil sands plants. Steam is produced and pumped into the oil-bearing formation to facilitate oil recovery. Demands can be large and the system is relatively complex. Most oil companies have not fully defined their system as yet.

"Other", storage, and diversion uses involve weir or dam construction, or channel modification for better conveyance of flows. In the remainder of this section, each type of system is reviewed individually in order to define the locations of

TABLE 3.1

POPULATION, BEAVER RIVER BASIN

	1911	1921	1931	1941	1951	1956	1961	1966	1971	1976	1980
Bonnyville	n.a.[2]	n.a.	362	603	1,139	1,495	1,736	2,237	2,587	2,873	4,256
Cold Lake	n.a.	n.a.	n.a.	n.a.	n.a.	1,097	1,307	1,289	1,309	1,303	1,648
Grand Centre	n.a.	n.a.	n.a.	n.a.	n.a.	1,008	1,493	1,731	2,088	2,751	3,107
Glendon	n.a.	n.a.	n.a.	n.a.	n.a.	314	315	350	354	366	454
Total Urban	n.a.	n.a.	362	603	1,139	3,914	4,851	5,607	6,338	7,293	9,465
C.F.B. Cold Lake	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4,530	5,917	6,305	5,434	5,500
Ardmore	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	172	245	230	n.a.	236
Fort Kent	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	148	91	113	n.a.	140
Other Rural	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5,359	4,726	4,287	n.a.	4,606
Total M.D. Bonnyville	841	2,515	5,254	7,571	6,744	10,058	10,209	10,979	10,935	9,848	10,482
Total Co. Athabasca[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	259	276
Mallaig	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	200
Rural	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1,400	1,290
Total Co. St. Paul[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1,400	1,490[4]
Total Co. Smoky Lake[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	232	247[4]
Total I.D. 18	70	208	850	1,687	1,186	1,067	1,041	1,096	1,097	1,931	2,055[4]
Beaver Lake I.R.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	202	263
Cold Lake I.R.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	552	1,019
Kehewin I.R.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	453	695
Whitefish Lake I.R.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	665	569
Total Indian Reserves[5]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	812	1,066	1,286	1,872	2,546
TOTAL	911	2,723	6,466	9,861	9,069	14,031	16,913	18,748	19,656	22,835	26,561

[1] 1911 - 1971 figures from Alberta Muncipal Affairs (1978); 1976 and 1980 figures based on enumeration areas and personal communications.

[2] n.a. means a figure is either not available or does not apply, and is assumed to be equal to zero.

[3] data were unavailable for the total for 1911 - 1971.

[4] assumes same rate of growth as M.D. Bonnyville (6.44% 1976 - 1980).

[5] data from Canada Indian and Northern Affairs, 1981.

water supply withdrawals and sewage returns. Reservoir capacities and water treatment methods are also discussed.

3.1 Domestic

Generally, domestic water use systems involve individual wells providing water for household and farm use. This use can be exempted from licencing under the Alberta Water Resources Act (Alberta, 1980). There are about 8500 rural residents in the basin - this includes 1578 Metis living in settlements. Each household has individual sewage disposal. The Metis Settlements generally use pit privies (Erasmus, 1981) while most other rural residents have septic systems - generally with an evaporation field (Shaw, 1981). Some houses may have holding tanks that require pumping out and trucking of sewage to municipal sewage lagoons.

Only five licences for domestic use exist in the basin. They all involve storage of spring runoff in a small reservoir for the purpose of stockwatering. Dams 1.8 to 5.5 m high in coulees have created reservoirs 0.4 - 1.2 ha in area. Total storage ranges from 3.4 dam^3 to 9.4 dam^3 (Water Rights Branch files).

3.2 Municipal

There are 18,087 people serviced by municipal water systems in the Beaver River basin. The majority of these people (11,274) are in the Cold Lake - Grande Centre area. These towns recently formed a Regional Utilities Board to improve the system by constructing and operating a joint system. Bonnyville has the second largest system servicing 4256 people. The remaining municipal systems are for small towns and Indian Reserves. Each system is detailed below.

3.2.1 Ardmore - Fort Kent

Ardmore (population 236) and Fort Kent (population 140) share a water supply system. A 51.8 m well is located between the two towns at SE32-61-04-W4. Iron removal and chlorination is carried out in a treatment plant located at the well. An underground reservoir provides storage for 135 m^3 of water.

Each town has its own sewage lagoon located south of town. Each is discharged once per year to Muriel Creek during spring runoff. The time of discharge is specified by the Municipal Engineering Branch of Alberta Environment.

3.2.2 Bonnyville

Bonnyville (population 4256) uses Moose Lake (2.4 km west of town) as its municipal water source. Water is pumped from Vezeau Bay to a water treatment plant where the water is filtered, aerated, fluoridated, and chlorinated. The town intends to build a new water treatment plant that will include water softening, but definite construction plans are not finalized (North, 1981). Water storage is provided by two reservoirs: an underground reservoir with a capacity of 900 m^3, and a tower with a capacity of 180 m^3. The existing sewage lagoons are on Jessie Lake and are discharged to Muriel Creek.

New sewage lagoons are being constructed in 1981 for the town on Charlotte Lake east of Bonnyville. At design level, the lagoon will be discharged twice a year to Muriel Creek. However, Suncor, Inc. is in the process of obtaining authorization to use the sewage effluent for deep well injection in their in-situ oil sands recovery process. In this case, there will be no discharge of sewage effluent to Muriel Creek.

3.2.3 Cold Lake - Grand Centre - CFB Cold Lake

Cold Lake (population 1648), Grand Centre (population 3107), and the Canadian Forces Base (CFB) (population 5500) have historically shared water supply facilities, but maintained separate sewage disposal facilities. Their close proximity, current operating problems and projected population growth have led to formation of a Regional Utilities Board. This Board will oversee water supply and sewage treatment for the towns and the CFB Cold Lake. The system involves common ownership and operation of:

- water intake
- water treatment plant
- water transmission pipelines
- treated water pumping stations
- sewage lift stations
- sewage forcemains
- sewage treatment plant

A design population of 18,000 was used for facilities such as pumps and treatment facilities that can be extended in stages. A design population of 35,000 was used for the collection system and other components that are difficult and costly to extend (W.J. Francl, 1979). Currently, the new water intake system and water treatment plant have been completed, but the sewage treatment system is still in the planning stages.

The new water intake system withdraws water from Cold Lake. The new water treatment plant includes ozonation, filtration, chlorination, and fluoridation.

Water is stored in reservoirs at Cold Lake, Grand Centre, and CFB Cold Lake. Cold Lake has one underground reservoir with a capacity of 4500 m^3. Grand Centre has two underground reservoirs with capacities of 275 m^3 and 2275 m^3. CFB Cold Lake has a reservoir with capacity of 3825 m^3.

Sewage is currently being treated by each municipality. Cold Lake has a facultative lagoon located at the northwest corner of NE22-63-2-W4 approximately 1.2 km west of town. Effluent is discharged twice per year into an improved drainage course which flows to the south and then to the west for a total of 8 km to drain into Marie Creek north of CFB Cold Lake. The lagoon was designed for a population of 2500 with sewage flows of 300 *l*/capita/day. It is presently running almost at capacity because of high flows, mainly due to groundwater infiltration into the sewers (W.J. Francl, 1979).

Sewage from Grand Centre is treated in a facultative lagoon located at SW34-62-2-W4 adjacent to the Canadian National Railway line. Effluent is discharged more than twice per year because of inadequate storage capacity. Discharge is to the railway ditch that leads to Marie Creek.

Sewage from CFB Cold Lake is treated by a mechanical sewage treatment plant. Effluent is discharged continuously to Marie Creek.

A new sewage treatment facility will be built to service Cold Lake and Grand Centre. Construction should start in 1982. Sewage from Cold Lake and Grand Centre will be collected and transmitted to a facultative lagoon adjacent to the Beaver River at NE21-62-2-W4. Provision for conversion to an aerated lagoon system will be made during construction.

3.2.4 Glendon

Glendon (population 454) withdraws water from Minnie Lake for municipal supply. Although the water licence was never fully processed, application was made in 1964 to withdraw 82.6 dam^3/year. The town has been operating with this application. When application was made in 1980 for withdrawal of 95 dam^3/yr., local residents complained that Glendon withdrawal caused the falling levels in Minnie Lake. Alberta Environment has, therefore, recommended that a well be drilled near Glendon and municipal supplies be changed from surface water to groundwater (Water Rights Branch file). The well was drilled in 1981. A groundwater withdrawal application has been filed for 497 dam^3/yr., but the licence has not been processed. Storage is provided in a reservoir with a capacity of 180 m^3.

Sewage is treated in a lagoon near the town that is discharged once per year into Columbine Creek. A new lagoon is planned for the future.

3.2.5 Indian Reserves

There are four Indian Reserves within the Beaver River basin - Cold Lake, Kehewin, Beaver Lake, and Whitefish Lake. Their total population is 2546. The majority of residents have water delivered to an individual cistern by a Reserve water truck. Only core area buildings are connected to distribution systems. This usually includes the school, teacher's home, and band administration building.

The largest reserve is Cold Lake I.R. #149, #149A, #149B, which has three land areas - a large one south of the towns of Cold Lake and Grand Centre, and two smaller ones on Cold Lake. I.R. #149 (south of Cold Lake - Grand Centre) is connected to the Cold Lake - Grand Centre - CFB Cold Lake distribution system from Cold Lake but only about 150 people are serviced directly.

The rest (870 people) have cisterns and are serviced by truck. Water is screened and chlorinated. A small sewage lagoon serves the core area. Most residences have individual pit privies.

The Kehewin I.R. #123 is located adjacent to Muriel Lake, Sinking Lake and Kehewin Lake. It is the only reserve with a provincial water licence. Water is supplied from Kehiwin Lake (Dalrymple, Roma and Associates, 1980). It is pumped a distance of 610 m to a water treatment plant located above an underground reservoir where the water is filtered and chlorinated. The reservoir holds 85 m^3 of water. A water truck supplies all buildings from the reservoir. A sewage lagoon serves the core area (school, band office and recreation centre).

Beaver Lake I.R. #131 is located southeast of Lac La Biche in the Beaver River headwaters. The residents are served entirely by groundwater wells and individual pit privies (Canada Indian and Northern Affairs, 1981).

The Whitefish Lake I.R. #128 is located east of Whitefish and Goodfish Lakes. Water is supplied from Whitefish Lake to a water treatment plant and concrete reservoir. Filtration and chlorination facilities are available, however, in 1979 neither were operable (Stanley Associates, 1980). Again, only core area facilities are served by a water distribution system. Waste water undergoes secondary treatment and is stored in a lagoon. Effluent flows into a bog area bordering Goodfish Lake. Most houses, however, have individual pit privies.

3.2.6 Mallaig

The town of Mallaig (population 200) siphons water from Denning Lake three miles west of town for its municipal water supply. Water is filtered and chlorinated at the lake intake. Storage is provided in an underground reservoir with a capacity of 150 m^3. Sewage is disposed of in a lagoon that is discharged to a farmer's field near Mallaig.

3.2.7 Others

Boyle (population 646), located three miles west of the western basin divide, withdraws water for municipal use from Skeleton Lake in the headwaters of the Amisk River. Water is pumped a distance of 4400 m to a treatment plant. Sewage, however, does not re-enter the basin. It is discharged to a creek that enters Flat Lake within the Athabasca River basin.

Therein (population 53) has individual wells. The hamlet is constructing a new sewage lagoon in 1981 that will discharge once per year to Columbine Creek, a tributary of the Beaver River.

3.3 Irrigation

There are only seven licences for irrigation in the Beaver River basin. The total irrigated area is 135 ha with fields varying from 7.7 - 31 ha. They are all small irrigation projects using water from surface water sources, usually sloughs.

3.4 Industrial

The industrial water systems in this basin consist almost exclusively of in-situ heavy oil recovery operations. There are currently 13 pilot plants in the basin operated by ten oil companies. Additionally, three companies plan future developments. All industrial uses require a licence. The locations of oil sands projects are shown in Figure 3.2.

The oil recovery processes and water systems are discussed below. For this study, three plant sizes were defined on the basis of oil production, as follows:

small - less than 1000 m^3/day heavy oil
medium - 1000 - 6000 m^3/day heavy oil
large - over 6000 m^3/day heavy oil

These categories are based on methods of effluent disposal that are explained below.

3.4.1 Oil Recovery Processes

Several recovery processes are being tested by the oil companies in the Cold Lake area. They are as follows:

Steam Stimulation

In this process, steam is injected into the oil bearing formation for a period of time until the bitumen becomes fluid. Steam injection is then stopped and the bitumen is pumped out through the well. The process is cyclic.

Steam Drive

This process is basically the same as steam stimulation except that one well is used for steam injection and one or several other wells for oil recovery. The steam injection is a continuous process. Some underground connections must be established between the injection and recovery wells.

In-Situ Burning

In this process some of the oil left in the formation is ignited and burned under a controlled environment in order to keep the bitumen in a fluid state. In-situ burning has to be preceded by approximately two years of steaming in order to bring the formation to a temperature where combustion can be self-sustained. Generally, large quantities of water are required during the initial steaming phase, however, some formations may actually generate rather than consume water. Subsequent water requirements drop considerably. Water is used mainly to control the combustion in the formation.

Presently only Dome Petroleum has indicated that they plan to use in-situ burning for oil recovery in the Cold Lake area.

3.4.2 Water Requirements for Oil Recovery

Water Use Ratios

Steam-oil and water-oil ratios are two key values in understanding water demands in process. Some oil companies treat the exact figure as confidential information.

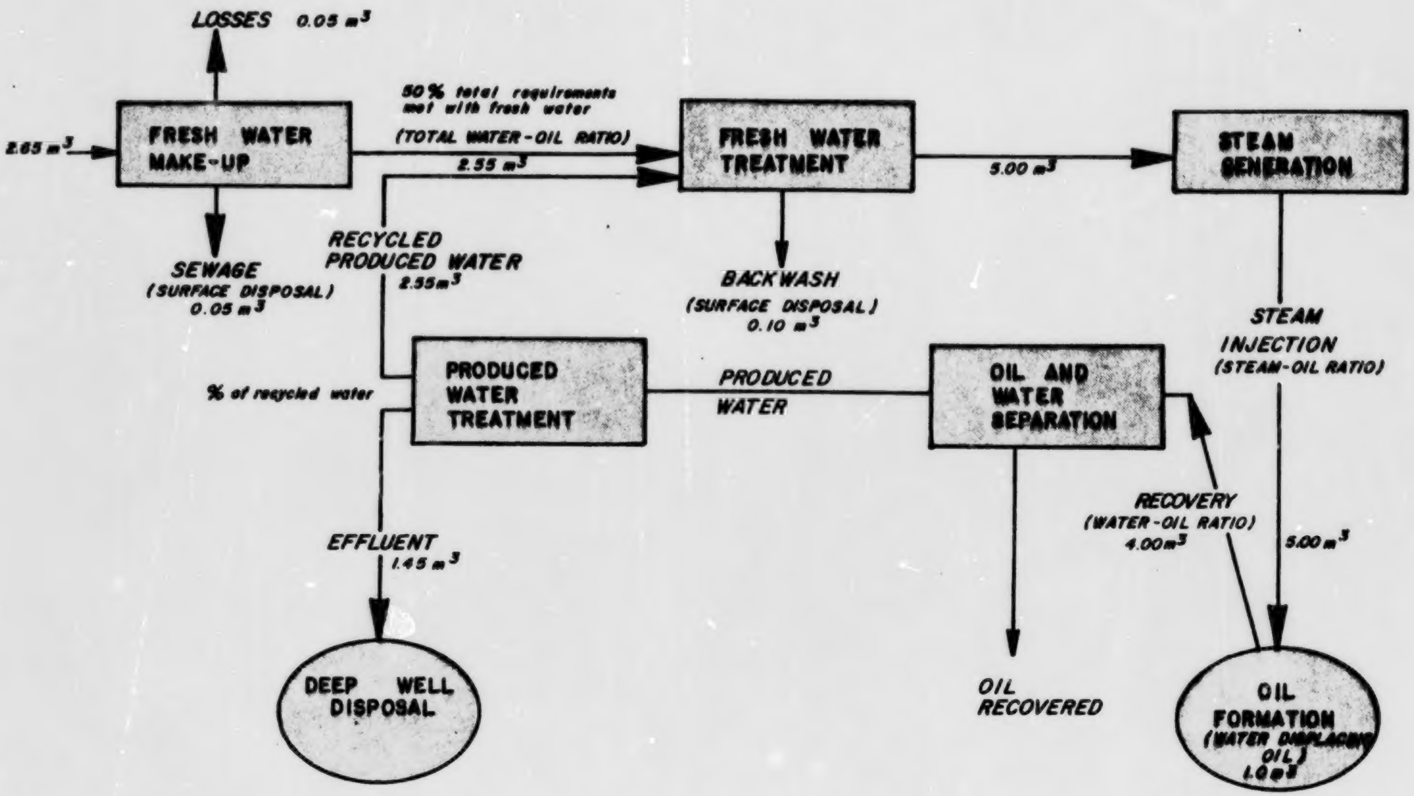
The *'steam-oil ratio'* gives the quantity of steam that has to be injected into the oil-bearing formation in order to recover a certain quantity of oil. It gives an indication of the energy efficiency of the system. A steam to oil ratio larger than ten is uneconomical as more energy is injected into the ground as steam than is recovered as oil.

The *'water-oil ratio'* is the ratio between the water and oil in the mixture that is pumped out of the formation. The water-oil ratio is an indicator of the reservoir efficiency. Ideally water recovered should be less than steam injected as some of the water is used to displace the oil in the formation. In practice, there is no fixed relation between the water-oil ratio and the steam-oil ratio; some formations may contain large quantities of water that will be pumped out producing quantities of water greatly in excess of the volume expected. A water-oil ratio between three and ten has been experienced by various oil companies in their present operations (personal communications with various companies, 1981). The most common value cited is four. In all cases, the ratio will vary from formation to formation and not all plants can be expected to achieve the same performance.

A third ratio, the *'total water-oil ratio'*, is used to calculate the overall water requirement associated with a given plant. This ratio is higher than the steam-oil ratio as it includes water for steam injection, backwash water from the fresh water treatment softening process and possibly blowdown water (excess water from the steam generators). A ratio of five to six would be average for a steam injection process. All water demands for oil sands projects in this report relate to the total water-oil ratio.

Water Management

Figure 3.3 illustrates a theoretical flow diagram of water management for a medium sized plant (1000-6000 m^3/day heavy oil) using water recycling. Water quantities are based mainly on the Esso application for a pilot plant extension. All quantities shown are in m^3 per m^3 heavy oil produced.


LOSSES 0.05 m³
2.65 m³
FRESH WATER MAKE-UP
SEWAGE (SURFACE DISPOSAL) 0.05 m³
50% total requirements met with fresh water
(TOTAL WATER-OIL RATIO)
2.55 m³
RECYCLED PRODUCED WATER 2.55m³
FRESH WATER TREATMENT
BACKWASH (SURFACE DISPOSAL) 0.10 m³
5.00 m³
STEAM GENERATION
STEAM INJECTION (STEAM-OIL RATIO)
5.00 m³
% of recycled water
PRODUCED WATER TREATMENT
PRODUCED WATER
OIL AND WATER SEPARATION
EFFLUENT 1.45 m³
DEEP WELL DISPOSAL
OIL RECOVERED
RECOVERY (WATER-OIL RATIO) 4.00m³
OIL FORMATION (WATER DISPLACING OIL) 1.0 m³

NOTE:

VALUES INDICATED ARE IN m^3 OF WATER PER m^3 OF PRODUCED OIL

RESULTS ARE BASED ON ASSUMPTION THAT 50% OF TOTAL REQUIREMENTS ARE MET WITH FRESH WATER

Figure 3.3

STEAM INJECTION PROCESS FLOW DIAGRAM WITH WATER RECYCLING

MacLaren Plansearch

The values shown on Figure 3.3 are based on the assumption that fifty percent of the total water requirements are not with fresh water. A total of 2.65 m^3 of fresh water is supplied to the plant. Some losses occur during storage (0.05 m^3) and some are used for domestic purposes and is surface disposed as treated sewage water (0.05 m^3). This leaves 2.55 m^3 of fresh water to be supplied to the steam generators along with 2.55 m^3 of water recycled after produced water treatment.

Total fresh supplied water is treated with lime softening, filtration and ion exchange softening. Backwash from the process keeps the treatment operational. About 0.1 m^3 of the backwash water from the ion exchange softening is disposed of to the surface water. Therefore, the total water to be surfaced disposed is 0.15 m^3 (0.05 m^3 from sewage plus 0.1 m^3 from backwash or approximately 3% of the total water requirement). A total of 5 m^3 is supplied to the steam generators. In most cases no blowdown (excess water) is generated and all the steam produced is injected into the oil formation.

One m^3 of water is left in the formation where its displaces the oil. Four cubic meters of water are recovered along with one cubic meter of oil. Those ratios of oil to water and water displacing oil could vary widely from formation to formation depending on the quantity of water present in the formation at the time of steaming. Oil and water are then separated, the oil is recovered and the produced water is deoiled and filtered. A portion is recycled (2.55 m^3) and the rest is disposed of in deep wells (1.45 m^3).

Disposed quantities of water as stated above are based upon Esso's proposed plans for its expanded pilot plant. Due to the lack of data from most of the oil companies, Esso's data have been used throughout the report to estimate the water quantities that will be disposed of by the other companies. At the time of production, each company's plan could call for slightly different processes that could lead to different quantities of actual effluents.

Current and Future Plant Management

There are currently ten plants in the Beaver River Basin. Only Esso Resources is operating at greater production than 1000 m^3 oil/day. Only small amounts of water are recycled by the current pilot plants. Produced water is reinjected into or below the oil bearing formation. Current Alberta Environment policy does not allow surface disposal of produced water. In most cases only backwash water is disposed of on the surface (Alberta Environment, Johnston, 1981).

During the interviews with MacLaren Plansearch staff, most companies recognized that when a plant exceeds approximately 1000 m^3 oil/day, part of the produced water will have to be recycled in order to decrease the overall freash water requirements. Most companies indicated that approximately 50 percent of the water requirements of a medium-sized plant could be met with recycled water.

In the case of a large plant (over 6000 m^3/day heavy oil), surface effluents could amount to 0.2 m^3 effluent per cubic meter of oil produced. An oil upgrader would be used which requires additional water and adds to the amount of effluent. Large plants would rcycle at least 50 percent of their produced water (based on Esso Resources' plans for a proposed 26,500 m^3/day plant). No large plants now exist.

3.5 Other

"Other" licences in the Beaver River basin are used for fur farming and fish or waterfowl propagation They sometimes involve building a dam to maintain the water level of a marsh, or to create fishponds. Not all licences have stated allocations. Some licences have allocations that are intended to represent the amount of evaporative losses from the water body. No water is actually withdrawn from the system by a user however, it was decided along with the Beaver River Water Resources Study Committee that the alteration to the streamflow would be accounted for in the streamflow records, and the streamflow model would not be adjusted for the presence of these projects.

3.6 Non-Consumptive Uses

Non-consumptive uses include storage and diversion uses. The storage licences are for lake stabilization and the diversion licences are for flood control or drainage. None of these licences involve actual withdrawal and consumption of water. Either the creek channel is straightened for better conveyance of flows or drainage of land, or a weir is built to stabilize lake or stream levels. While all these demands are essentially non-consumptive, they do alter the downstream flow regime. However, small alterations in streamflow regime like these are not considered significant by Environment Canada. They still report the Beaver River as a natural flow stream (Environment Canada, 1981).

CURRENT WATER DEMANDS

4.0 CURRENT WATER DEMANDS

Water users demand both a quantity and a quality of water suitable to their specific purpose. Data from this report will be used as imput to a water balance model that will determine the balance between water supplied within the river system and the water demand made by the users. This section details the water demands as they existed in 1980.

Water users also require water of a quality suitable to their purpose. Water treatment may be necessary in order to meet the criteria for a certain purpose. Regulations prevent discharge of highly polluted water to a surface waterbody. These factors will be taken into account in the water quality model to be run with these water quantity data.

4.1 Water Quantity Demands

Under the Water Resources Act, all withdrawals except those under Section 5 (mainly domestic uses) require a licence from Alberta Environment. These licences detail the amount of water authorized, the source of supply, diversion point and other pertinent data. Large users are required to submit annual reports detailing how much water is actually diverted (versus the maximum licenced diversion). Some purposes require a licence, but are non-consumptive users, for example, licences for weirs or channelization. In the Alberta portion of the Beaver River basin, there are 94 active licences and 11 cancelled licences. There are none in the Saskatchewan portion of the basin (Nargang, 1981). The active licences are divided between purposes as follows:

Domestic	5
Municipal	10
Irrigation	7
Industrial	25
Other	11
Storage	6
Diversion	30
Total Active Licences	94

All licences are listed in Appendix A. In actuality, all water uses are not licenced. Some uses are authorized, which means that approval has been given to construct the project and operate it until a licence is issued. Other licences are still in the application processing stage for the purpose of this study, the amount requested in the application was taken as the amount authorized. All authorized and licenced demands were quantified by reach and by prupose. A reach is defined as the drainage area between the node specified and the node immendiately upstream.

Several assumptions were necessary in the calculation of actual wthdrawal and return amounts as follows:

- The full amount of water authorized or licenced is consumed for irrigation, stockwatering, and in-situ steam injection, that is, there are no return flows for any of these purposes.
- None of the water authorized or licenced for diversion or storage used for drainage, flood control, or lake stabilization is actually withdrawn. These licences are usually required for the construction of weirs or channelization. Licences for steam trains under "others" are considered inactive and involve no withdrawal.
- Water allocated for the remaining "other" uses, especially waterfowl propagation is consumed by evaporation, but is ignored here since the effect of the projects has become part of the long-term hydrologic regime of the rivers and lakes. No withdrawal of water by man occurs.
- Municipal returns equal 80 percent of municipal withdrawals.

Two exploration permits have been granted by the Ground Water Rights Branch. These permits are for one year only (with the possibility of extension) but they carry no right to divert and use water, and therefore are not included in the tables in Appendix A. If the exploration proves successful, the company may proceed with an application for a licence. Exploration permits do not carry any compulsory right to the use of water. The exploration permits are:

- Dome Petroleum Ltd.; file no. 16232; located at 67-4-W4; for 477.7 dam^3/yr
- Esso Resources Canada Ltd.; file no. 14404; located at 64-3-W4; for 331.7 dam^3/yr

There are additional water demands that are not authorized or licenced. One Indian Reservation has not been licenced for withdrawal. Rural residences using water for domestic purposes are exempted from licencing. Both of these demands are considered in Section 4.1.3.

Seasonal variations that occur in water demands will be detailed in Section 4.1.4. Average monthly water demands are quantified for each purpose.

4.1.1 Authorized Demands by Reach

Reaches of the Beaver River and tributaries were defined for computer modeling purposes (Nanuk Engineering and Development Ltd., 1981). The Water Balance Model Schematic (Figure 4.1) details each reach number and its location. Under high flow conditions, Reita Lake (Reach 227) drains to Muriel Lake (Reach 223) rather than Angling Lake (Reach 228). This is the natural condition which was altered by channelization in the early 1960's.

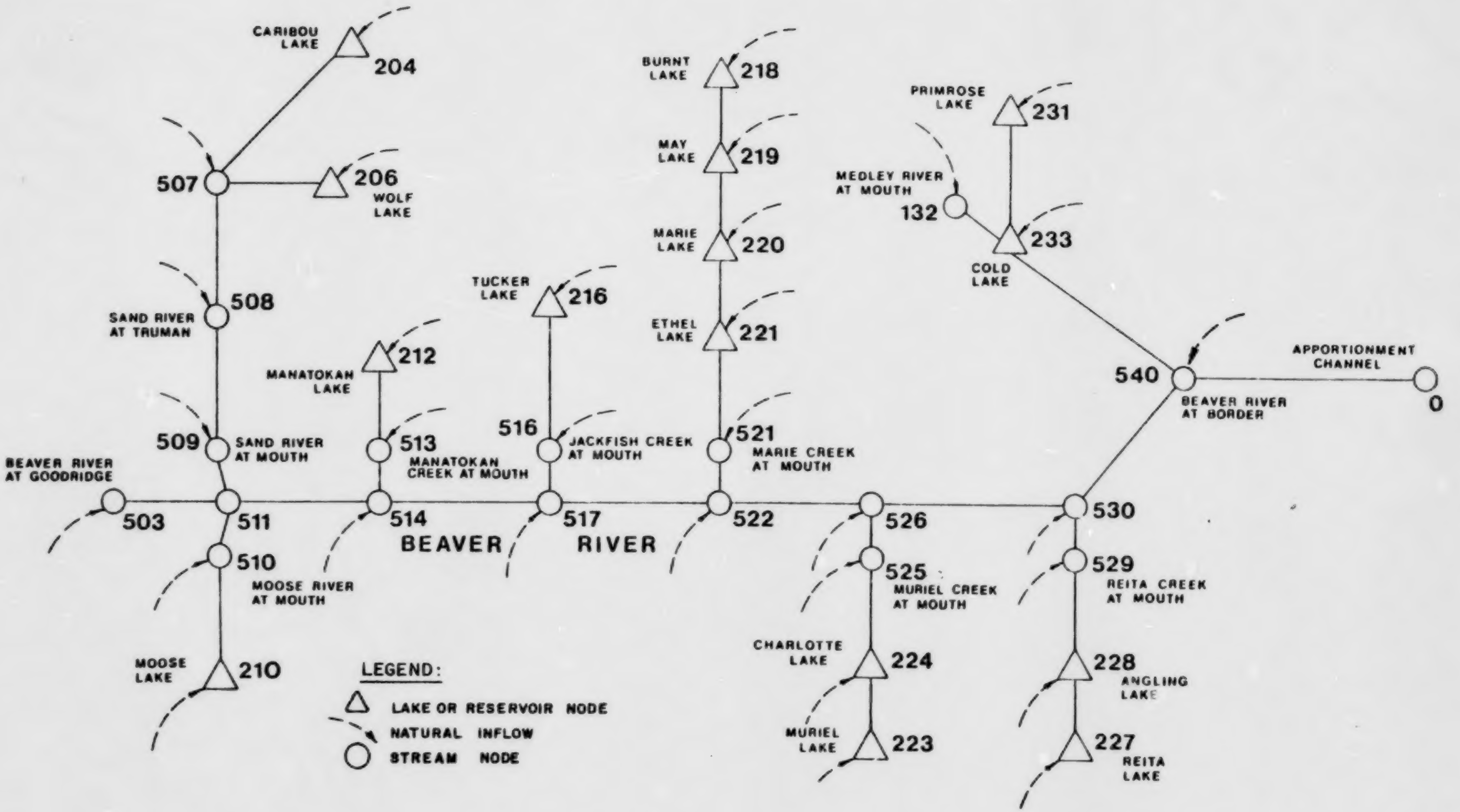

CARIBOU LAKE
204
507
206
WOLF LAKE
508
SAND RIVER AT TRUMAN
509
SAND RIVER AT MOUTH
BEAVER RIVER AT GOODRIDGE
503
511
510
MOOSE RIVER AT MOUTH
MOOSE LAKE
210
MANATOKAN LAKE
212
513
MANATOKAN CREEK AT MOUTH
514
BEAVER
TUCKER LAKE
216
516
JACKFISH CREEK AT MOUTH
517
RIVER
BURNT LAKE
218
MAY LAKE
219
MARIE LAKE
220
ETHEL LAKE
221
521
MARIE CREEK AT MOUTH
522
526
525
MURIEL CREEK AT MOUTH
CHARLOTTE LAKE
224
MURIEL LAKE
223
PRIMROSE LAKE
231
MEDLEY RIVER AT MOUTH
132
233
COLD LAKE
540
BEAVER RIVER AT BORDER
APPORTIONMENT CHANNEL
0
530
529
REITA CREEK AT MOUTH
228
ANGLING LAKE
227
REITA LAKE
LEGEND:
LAKE OR RESERVOIR NODE
NATURAL INFLOW
STREAM NODE

Figure 4.1

COLD LAKE - BEAVER RIVER BASIN
WATER BALANCE MODEL SCHEMATIC

SOURCE: NANUK ENGINEERING AND DEVELOPMENT LTD., 1981

Thirteen reaches had no licences and are omitted from further details. They are reaches:

- 0
- 204
- 218
- 219
- 220
- 227
- 228
- 231
- 507
- 508
- 513
- 514
- 522

A summary of authorized and licenced water withdrawals and returns for each reach is found in Table 4.1.

Details on active authorizations and licences within each reach are found in Appendix B.

4.1.2 Authorized Demands by Purpose

Table 4.2 summarized active authorized and licenced withdrawals and returns by purpose. Surface water is the largest source with 30,708 dam^3/yr authorized or licenced for withdrawal. Only 15 percent of this amount (4686 dam^3/yr) was actually withdrawn in 1980. A total of 3549 dam^3/yr (76 percent of 1980 withdrawals) was returned. If all authorized or licenced withdrawals were utilized, ultimately 11,525 dam^3/yr could be returned to the system (based on the same proportion being returned for each purpose).

Groundwater withdrawals are much less than surface water withdrawals. Only 3496 dam^3/yr are authorized or licenced for withdrawal while 48 percent of this amount (1850 dam^3/yr) was actually withdrawn in 1980. Withdrawals for municipal and diversion purposes are not

TABLE 4.1

SUMMARY OF LICENCED WATER WITHDRAWALS AND RETURNS BY REACH

	SURFACE WATER (dam^3/yr)				GROUND WATER (dam^3/yr)			
	WITHDRAWAL		RETURN		WITHDRAWAL		RETURN	
	AUTHORIZED OR LICENCED*	1980	ULTIMATE	1980	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980
Reach 132								
Industrial	-	-	-	-	801.8	139.4	0	0
Other	9.9	9.9	9.9	9.9	-	-	-	-
Reach 206								
Industrial	-	-	-	-	471.2	189.8	0	0
Reach 210								
Domestic	2.5	2.5	0	0	-	-	-	-
Municipal	921.4	926.2	115.4	75.4	-	-	-	-
Irrigation	145.6	145.6	0	0	-	-	-	-
Industrial	124.6	0	0	0	-	-	-	-
Diversion	0	0	0	0	-	-	-	-
TOTAL	1194.1	1074.3	115.4	75.4				
Reach 212								
Diversion	0	0	0	0	-	-	-	-
Reach 216								
Other	0	0	0	0	-	-	-	-
Reach 221								
Industrial	1541.8	1279.1	0	0	-	-	-	-
Other	123.4	0	0	0	-	-	-	-
Storage	0	0	0	0	-	-	-	-
TOTAL	1665.2	1279.1	0	0				
Reach 223								
Industrial	732.7	45.6	0	0	-	-	-	-
Reach 224								
Irrigation	30.8	30.8	0	0	-	-	-	-
Municipal	-	-	621.7	641.5	-	-	-	-
Industrial	3441.4	0	0	0	-	-	-	-
Storage	0	0	0	0	-	-	-	-
Diversion	0	0	0	0	-	-	-	-
TOTAL	3472.2	30.8	621.7	641.5				

TABLE 4.1 CONTINUED

	SURFACE WATER (dam^3/yr) WITHDRAWAL AUTHORIZED OR LICENCED*	SURFACE WATER WITHDRAWAL 1980	SURFACE WATER RETURN ULTIMATE	SURFACE WATER RETURN 1980	GROUND WATER (dam^3/yr) WITHDRAWAL AUTHORIZED OR LICENCED	GROUND WATER WITHDRAWAL 1980	GROUND WATER RETURN ULTIMATE	GROUND WATER RETURN 1980
Reach 233								
Municipal	11903.1	1955.6	922.6	879.4	-	-	-	-
Industrial	0	0	0	0	-	-	-	-
Diversion	0	0	0	0	-	-	-	-
TOTAL	11903.1	1955.6	922.6	879.4				
Reach 503								
Domestic	13.6	13.6	0	0	-	-	-	-
Municipal	124.6	127.0	10.9	15.8	-	-	-	-
Irrigation	104.8	104.8	0	0	-	-	-	-
Industrial	90.0	0	0	0	-	-	-	-
Other	11181.5	0	0	0	-	-	-	-
Storage	0	0	0	0	-	-	-	-
Diversion	0	0	0	0	-	-	-	-
TOTAL	11514.5	245.4	10.9	15.8				
Reach 509								
Industrial	-	-	-	-	172.7	0	0	0
Reach 510								
Other	0	0	0	0	-	-	-	-
Reach 511								
Diversion	0	0	0	0	-	-	-	-
Reach 516								
Diversion	0	0	0	0	-	-	-	-
Reach 517								
Industrial	-	-	-	-	165.3	0	0	0
Diversion	0	0	-	-	-	-	-	-
Reach 521								
Municipal	-	-	6907.5	230.2	-	-	-	-
Storage	0	0	0	0	-	-	-	-
Diversion	-	-	1204.0	1204.0	1204.0	1204.0	0	0
TOTAL	0	0	8111.5	1434.2	1204.0	1204.0	0	0

TABLE 4.1 CONTINUED

	SURFACE WATER (dam^3/yr)				GROUND WATER (dam^3/yr)			
	WITHDRAWAL		RETURN		WITHDRAWAL		RETURN	
	AUTHORIZED OR LICENCED*	1980	ULTIMATE	1980	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980
Reach 525								
Municipal	-	-	40.4	37.8	50.6	47.2	-	-
Industrial	-	-	-	-	334.2	202.3	0	0
Diversion	0	0	0	0	-	-	-	-
TOTAL	0	0	40.4	37.8	384.8	249.5	0	0
Reach 526								
Industrial	-	-	-	-	296.0	67.0	0	0
Reach 529								
Diversion	0	0	0	0	-	-	-	-
Reach 530								
Municipal	-	-	1692.3	454.9	-	-	-	-
Reach 540								
Irrigation	43.2	43.2	0	0	-	-	-	-
Industrial	172.7	0	0	0	-	-	-	-
TOTAL	215.9	43.2	0	0				

* Many "other", storage and diversion licences are non-consumptive; therefore, often no withdrawal amount is stated in the licence.

TABLE 4.2

SUMMARY OF LICENCED WATER WITHDRAWALS AND RETURNS BY PURPOSE

	SURFACE WATER (dam^3/yr)				GROUND WATER (dam^3/yr)			
	WITHDRAWAL		RETURN		WITHDRAWAL		RETURN	
	AUTHORIZED OR LICENCED*	1980	ULTIMATE	1980	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980
Domestic	16.1	16.1	0	0	-	-	-	-
Municipal	12949.1	3008.8	10310.8	2335.0	50.6	47.2	0	0
Irrigation	324.4	324.4	0	0	-	-	-	-
Industrial	6103.2	1324.7	0	0	2241.2	598.5	0	0
Other	11314.8	9.9	9.9	9.9	-	-	-	-
Storage	0	0	0	0	-	-	-	-
Diversion	0	0	1204.0	1204.0	1204.0	1204.0	0	0
TOTAL	30707.6	4685.9	11524.7	3548.9	3495.8	1849.7	0	0

* Many "other", storage and diversion licences are non-consumptive; therefore, often no withdrawal is stated in the licence.

returned to groundwater. Most industrial groundwater withdrawals are heated to produce steam that is injected back into the ground for oil recovery, but the injection is not to groundwater aquifers.

4.1.3 Unlicenced Demands

Under the Water Resources Act, a licence is not required to withdraw surface water or groundwater for use on an individual farmstead. Rural residents generally use less water than urban residents. It was assumed that urban residents use an average of 450 *l*/capita/day from a municipal water source, while rural residents use 350 *l*/capita/day from groundwater wells (North, 1981). With 6896 rural residents (excluding Metis) total groundwater withdrawal amounts to 881 dam^3/yr. Sewage is disposed of through individual systems. The water returned either to the groundwater or surface water systems is negligible. The water evaporates away from the septic field or is returned as soil moisture.

In addition to rural residents discussed above, there are 1578 Metis living in settlements. Their water consumption is typically very low - perhaps 200 *l*/capita/day (Canada Indian and Northern Affairs, 1981). They are serviced by individual wells, and use individual outdoor disposal facilities. Total groundwater withdrawal is calculated to be 115 dam^3/yr with no returns.

Water consumption in Indian Reserves is also very low - 250 *l*/capita/day for residences on a distribution line, and 150 *l*/capita/day for residences serviced by a water truck or individual wells (Canada Indian and Northern Affairs, 1981). Cold Lake I.R. is served by the Cold Lake - Grand Centre - CFB system from Cold Lake, however, only 150 people are on a distribution line. The remaining 870 people are serviced by truck. Total water demand is 61.3 dam^3/yr. Only 13.7 dam^3/yr sewage effluent is returned to the surface water system. The remainder is disposed of in individual pit privies or septic systems and is essentially lost (47.6 dam^3/yr).

The 1980 population of Whitefish I.R. was estimated by Canada Indian and Northern Affairs (1981) to be 569. Water demand was estimated to be 160 *l*/capita/day, somewhat higher than usual for unserviced houses because of a dry cleaning plant that utilizes 12.8 dam^3/yr water (Stanley Associates, 1980). Total water demand was estimated at 33.2 dam^3/yr from Kehewin Lake. Sewage flows were 27.5 dam^3/yr with 12.8 dam^3/yr from the dry cleaning plant. The remaining 5.7 dam^3/yr is lost to the system as it is disposed of in individual systems.

Beaver Lake I.R. is serviced by groundwater wells. Individual demand remains low. For the population of 263, total water demand is estimated at 14.4 dam^3/yr. There is no groundwater or surface water return flow as each residence has individual disposal.

Unlicenced water demands are summarized in Table 4.3.

4.1.4 Seasonal Demands

Water demands are not always evenly distributed over the year. The water balance model to be run with this data requires monthly data. Monthly variations should therefore be identified. Each purpose is examined individually.

Domestic

Domestic uses include individual farmstead water supply and farmyard stockwatering. Water demands for human consumption

TABLE 4.3

UNLICENCED WATER DEMANDS, BEAVER RIVER BASIN, 1980

	REACH NUMBER	SURFACE WATER (dam^3/yr) WITHDRAWAL	SURFACE WATER (dam^3/yr) RETURN	GROUND WATER (dam^3/yr) WITHDRAWAL	GROUND WATER (dam^3/yr) RETURN
Rural Residents	various	-	-	881	0
Metis Settlements					
Metis Colony 7	503	-	-	75	0
Metis Colony 9	0	-	-	40	0
Indian Reserves					
Beaver Lake	503	-	-	14	0
Cold Lake	233	61	14	-	-
Whitefish Lake	503	33	28	-	-
TOTAL	-	94	42	1010	0

are assumed not to vary to a great extent through the year. Stockwatering supplies, however, are diverted into reservoirs during spring runoff. Storage is then enough to supply water for the rest of the year. With the assumption that spring runoff occurs in the area during May, the total authorized diversion of 15.6 dam^3/yr for stockwatering occurs in one month.

Municipal

Monthly water consumptions are available for four communities in the basin: Ardmore-Fort Kent, the Town of Bonnyville, CFB Cold Lake and the Town of Cold Lake. Records from 1980 do not show a consistent seasonal demand from the towns (see Table 4.4). Typically, communities have consumption that peak during the summer. These northern towns do not show this trend. Consumptions are high in this area during the winter for two reasons: taps are left running to prevent freezing of water pipes, and second, when water pipes break, the spilled water adds significantly to the monthly demand for a small town. Consumptions for CFB Cold Lake are not indicative of typical seasonal variation either, since their figures include demands from the base and the townsite. Water use is by regular and visiting personnel. Data from the one year available is biased by the weather that year. To produce typical monthly variations, many years of data would need to be analysed. As a result, for this study, monthly municipal consumption was taken as 8.33 percent (one twelfth) of the yearly total. This approach was confirmed by Alberta Environment (Barlishen, 1981).

Irrigation

Only 135 ha of land are irrigated in the Beaver River basin as a result of relatively high precipitation in the region. The seven licences all pump small amounts of water from sloughs or lakes during the three summer months (June, July, August) for pasture

TABLE 4.4

CURRENT WATER WITHDRAWALS

1980 MONTHLY MUNICIPAL WATER DEMANDS

	ARDMORE-FORT KENT	BONNYVILLE	CFB COLD LAKE	COLD LAKE
MONTHLY DEMAND (percent)				
January	7.8	8.3	9.6	7.2
February	11.7	7.9	8.2	7.4
March	9.3	11.4	7.8	9.3
April	10.6	9.5	7.2	10.4
May	10.8	8.0	7.7	10.6
June	8.9	8.7	7.3	8.8
July	7.2	8.6	9.2	10.2
August	5.1	8.2	7.2	6.9
September	6.8	6.9	8.7	7.0
October	5.3	7.8	7.7	7.6
November	6.8	7.0	8.6	6.6
December	9.8	7.8	11.0	8.3
TOTAL	100.0	100.0	100.0	100.0
TOTAL DEMAND (dam^3/yr)	47.2	800.3	1099.3	287.7

or crops of grain. Total authorized diversion amounts to 324.4 dam^3/yr or 108.1 dam^3/month for three months. Actual diversion may be less than these amounts and may vary from year to year.

Industrial

Most industrial water use is for recovery of in-situ oil sands. These operations continue year-round and although some pilot plants use water on rotating monthly bases (one or several months of use followed by one or several months of zero use), this is not the usual case. Water demand variations are influenced by the plant operation cycle which is not related to seasons. Water demands were taken here as the same for each month.

Other

Some "other" uses have large allocations that cover the loss to evaperation from the water body. This occurs during the summer months. The replenishment of water supply to the water body generally occurs during spring runoff. However, for the purposes of this study, this factor was considered to be already shown in the streamflow records, and was therefore ignored.

Non-Consumptive Uses

The purposes of storage and diversion add little to seasonal fluctuation in water use. Some flow pattern modification can be expected mainly during peak flows but these modifications are already shown in the flow records. Typically, the weir installed holds back flows fir the use later in the season; or the channelization causes flows to move down the creek more quickly, thereby alleviating flooding.

4.2 Water Quality Criteria

Increased water quantity demands in the basin may alter the water quality. Water quality criteria have been established by industry and government for various uses. The water resources of the basin must be protected from deteriorating water quality while providing water of a suitable quality for municipal and industrial uses. The water quality model will simulate the effects of various levels of municipal and industrial development on the surface water quality.

Three categories of water quality criteria important in this basin are:

- treated water for municipal and industrial use
- municipal and industrial effluents discharged to surface water
- surface water quality objectives.

Each set of criteria is introduced below. Details on each set of criteria are included in Appendix C.

Treated Water Criteria

Water used for drinking and industrial purposes (in the heavy oil sands extraction processes) are treated to acceptable levels. The federal government has outlined the drinking water guidelines (Health and Welfare Canada, 1979) (See Appendix C-1). All water used for domestic and municipal purposes should meet these criteria after treatment. Some allowance is made by local health units for local conditions (Alberta Social Services and Community Health, 1981).

Three types of water within the heavy oil sands extraction are discussed here:

- boiler make-up water
- cooling water
- process/utility water

Small and medium sized plants (up to 6000 m^3day heavy oil) require only boiler make-up water plus small amounts of drinking water. Raw water is treated to boiler water quality to produce steam for injection. The level of treatment required depends on the pressure level achieved in the boiler. This is determined by the plans of the individual company. The boiler make-up water quality criteria considered by Esso Resources is presented in Appendix C-2.

Large plants with an upgrader also require cooling water and process/utility water. Cooling water is used to control operating temperatures and to condense gases. Water quality requirements are not as stringent for cooling water as for boiler feedwater. Process waters come in contact with the oil products. Utility waters are used for cleaning around the plant. Process and utility waters have similar quality requirements that are less stringent than cooling waters. Quality criteria for cooling water and process/utility water are presented in Appendix C-3 and C-4.

Effluent Criteria

Effluents including those from municipal sewage treatment facilities and from medium to large sized heavy oil plants are regulated by the Alberta government (Alberta Environment, 1978; Esso Resources Canada Ltd., 1981). All sewage effluents in the Beaver River basin are treated to the secondary level. All sewage must meet the criteria presented in Appendix C-5 before discharge to surface waters.

Prediction of the water quality of effluents from future heavy oil extraction plants was difficult. Small plants such as those in operation now do not discharge any wastes to surface waters. Medium sized plants will discharge some backwash waters, however. The quality of the backwash waters was estimated from data provided to Alberta Environment by Esso Resources, who have an operating plant near Ethel Lake (Alberta Environment, Johnston, 1981) (Appendix C-6). Esso also provided data on their proposed large sized plant effluents (Esso Resources Canada Ltd., Schindel, 1981). Those effluents would be discharged in amounts related to the flow of the Beaver River. Deposits to the Beaver River are presented in Appendix C-7.

Surface Water Quality Objectives

Ambient surface water quality objectives have been established in Alberta Surface Water Quality Objectives (Alberta Environment, 1978). These objectives as quoted below are designed to help in:

> "determining the capacity of a receiving watercourse to assimilate water contaminants which originate from natural sources and municipal and industrial liquid effluents. Waste load allocations for end of pipe discharges can be budgeted upon implementation of best practicable control technology and industrial performance guidelines in conjunction with consideration of these ambient surface water quality management point of view." (forward)

The individual cases exceeding the objective due to natural causes are reviewed accordingly by Alberta Environment. The objectives are presented in Appendix C-8.

The Prairie Provinces Water Board (PPWB, 1979) has set interim water quality requirements for the PPWB monitoring station

"Beaver River at Cold Lake Reserve" (06AD006) near the Alberta-Saskatchewan border. The Board reserved the right to recommend water quality requirements under the Master Agreement on Apportionment (Canada, P.C., 1969). In Schedule A, Section 3 of the apportionment agreement, Alberta is obligated to maintain the river at a comparable quality to its present state. These criteria are presented in Appendix C-9.

FUTURE WATER DEMANDS

5.0 FUTURE WATER DEMANDS

In the Beaver River Basin, demands for water in the future will depend on the level of future industrial development. If oil sands extraction proceeds on a large scale, water withdrawals for industrial purposes could amount to 80 percent of the total withdrawal. Otherwise, industrial use could remain at the current proportion of 30 percent of the total withdrawal.

For this study, two development levels (low and high) were identified for each of the study years: 1985, 2000 and 2015. Population projections were made based on these development scenarios. Water demands were then calculated for domestic, municipal, irrigation, and industrial purposes.

5.1 Industrial Development Scenarios

Future industrial development was based on personal interviews with representatives of each oil company holding a lease in the Cold Lake area. Several impressions of the future of development were formed as a result of these interviews.

At the present time, in-situ oil recovery technology is in its beginning stages. Esso Resources is generally recognized as a leader in the field and the rest of the companies watch Esso Resources' planning closely. Several agreements exist between oil companies to buy or to have access to data produced from other pilot plants. Some companies indicated that they would rather go into partnership with Esso than start plants on their own, if possible. Some of the oil companies recognize the advantage of being near an Esso Resources' plant to possibly permit use of some of Esso Resources' fresh water supply and/or treatment facilities planned by them.

Current and projected heavy oil production for each company having future plans is presented in Table 5.1. The number of plants of each size is included. The low development scenario represents the minimun activity planned for the future in case of non-favorable economic development. The high development scenario represents the maximum amount of activity planned in case of favorable economic development.

Water demand projections to the year 2015 were qualified by most companies as "best guesses". The high and low development scenarios attempt to bracket the range of possibilities. Many companies' pilot plant operations are not advanced enough to allow a fair estimate of the economics of the process. The uncertainties surrounding the oil pricing at the time of the survey made most companies unwilling to commit themselves.

At the present time, there are nine companies with small plants, and one with a medium plant (Esso Resources actually has several plants on their lease) for a total production of heavy oil of about 2000 m^3/day.

All companies, except Dome, have elected to use a steam stimulation process followed by steam drive. Dome has plans to use an in-situ burning method on which little data is available. These methods were outlined in section 3.4.1.

The low development scenario shows that maximum heavy oil production would increase only 3.5 times over the current level by the year 2000. No large plants would be built and there would be a decrease in the number of plants. Several companies indicated that if they did not have a commercial operation by 2000, they would never have one, and would therefore close their pilot plant operations. Production would decrease by 2015 as more pilot plants would close operations.

TABLE 5.1

CURRENT AND PROJECTED HEAVY OIL PRODUCTION - BEAVER RIVER BASIN (m^3/DAY)

	CURRENT	1985		2000		2015	
		LOW	HIGH	LOW	HIGH	LOW	HIGH
Amoco	16*	0*	800*	0*	3200*	0*	0
BP	Up to 160*	500	1000	1000	2000	1000	2000
Canada-Cities	0*	0	190	190	700	0	700
Chevron	40*	50	250	0	1000	0	1000
Dome	0	170	170	0	17800*	0	17800*
Esso	1580*	2200*	2200*	2200*	25500*	2200*	25500*
Gulf	0	0	320*	0	1600*	0	1600*
Husky	0	0	75*	0	1100*	0	1100*
Mobil	0	2	220	430	3200*	0	3200*
Murphy	16*	180*	300*	900*	1700*	2500*	5100*
Norcen	up to 10*	10	10	640*	2400*	640*	2400*
Petro Canada	40*	220	260	220	2200	0	1200
Suncor	170*	800*	800*	1600	3200	0	0
Union Texas	20*	250*	400*	250*	1600*	250*	1600*
TOTAL PRODUCTION	2052	4382	6995	7420	67200	6590	63200
# small plants	9	10	12	6	1	2	2
# medium plants	1	1	2	3	11	3	8
# large plants	0	0	0	0	2	0	2

* Value supplied by the oil company. Other values were calculated from the total water to oil and steam to oil ratios as supplied by the company (or assumed 6:1 total water to oil ratio when necessary).

The high development scenario indicates a very large expansion of operations by the year 2000. Production would increase over three times by 1985 and 32 times by 2000. Operations would expand from only one medium-sized plant to eleven medium plants and two large ones. By 2015, production would start to decline as plant operations would be phased out as the source of heavy oil would be depleted.

The following companies have leases in the study area but currently do not have plans for development:

- Amerada Minerals Corporation of Canada Ltd.
- Aquitaine Company of Canada Ltd. - in a joint venture with Chevron.
- Great Northern Oil Ltd. - in a joint venture with Union Texas and will probably remain in that role.
- Yellowknife Bear Mines Ltd. - have access to Esso and Norcen information and are likely to form a joint venture with Norcen.
- Texaco Canada Resources Ltd.

5.2 Population Projections

Future municipal water demands will depend on the number of people that settle in each town or village. This will depend, in turn, on how much oil sands development occurs. There are two components, however, to the increase in total population. One is the natural increase in population considering fertility and mortality rates, and in- and out-migration rates The other is the increase due directly to the industrial development projected to occur in 1985, 2000 and 2015. Both must be considered.

The existing population of the basin was estimated at 26,560 (see Table 3.1). This population increases naturally over time and is not subject to a low or high scenario described above. The most recent estimations of population increases for 1980-1991 have been done by Alberta Treasury, Bureau of Statistics (1980). Their percentage increases for this area (Census Division 12, Series 5) were used to estimate future growth. Growth past 1991 was taken at a uniform 3.71 percent per year (an extension of Alberta Treasury 1987-91 levels). Future basin populations were, therefore, estimated to be:

1985	29,870	people
2000	48,550	people
2015	80,100	people

In addition, the Town of Boyle, outside of the basin, will have populations in 1985, 2000, and 2015 of 750, 1290, and 2230 people respectively (using the same assumptions).

Extensive work has been done regarding population projections for the Cold Lake - Grande Centre area using various development assumptions (Alberta Advanced Education, 1979; Alberta Municipal Affairs, 1978; Alberta Treasury, 1980; Resources

Management Consultants, 1979). An amalgamation of efforts for the Cold Lake Regional Plan produced the projections used in this study (Alberta Municipal Affairs, 1979). Their development assumptions, however, do not coincide with those made in this study, since the study area does not include all of the Beaver River basin, and the time frame is too short (only to 1999). The assumed development levels were higher than ours, however, so increased development to 2015 could be accommodated. Since the majority of population increase would occur within the region of study for the Alberta Municipal Affairs study, their population increases were assumed as the total for all of the basin.

When total oil production and projected population increase from the Alberta Municipal Affairs study were plotted by MacLaren Plansearch (see Figure 5.1) a linear relationship was found (r^2 = 0.99 for over 20,000 m^3/day oil production). This graph was used to calculate population increases over oil production levels. These oil production levels (from Table 5.1) are plotted on Figure 5.1 as well. Population increases due to oil sands development are therefore calculated from the graph to be:

	LOW	HIGH
1985	2200 people	3400 people
2000	3700 people	31,800 people
2015	3000 people	30,000 people

These population increases must be taken as approximate, however, since many factors could come into play in the next 30 years to influence the totals.

Distribution of the future populations also becomes important as water systems must be sized for the population. Projections of existing populations were distributed as they currently are.

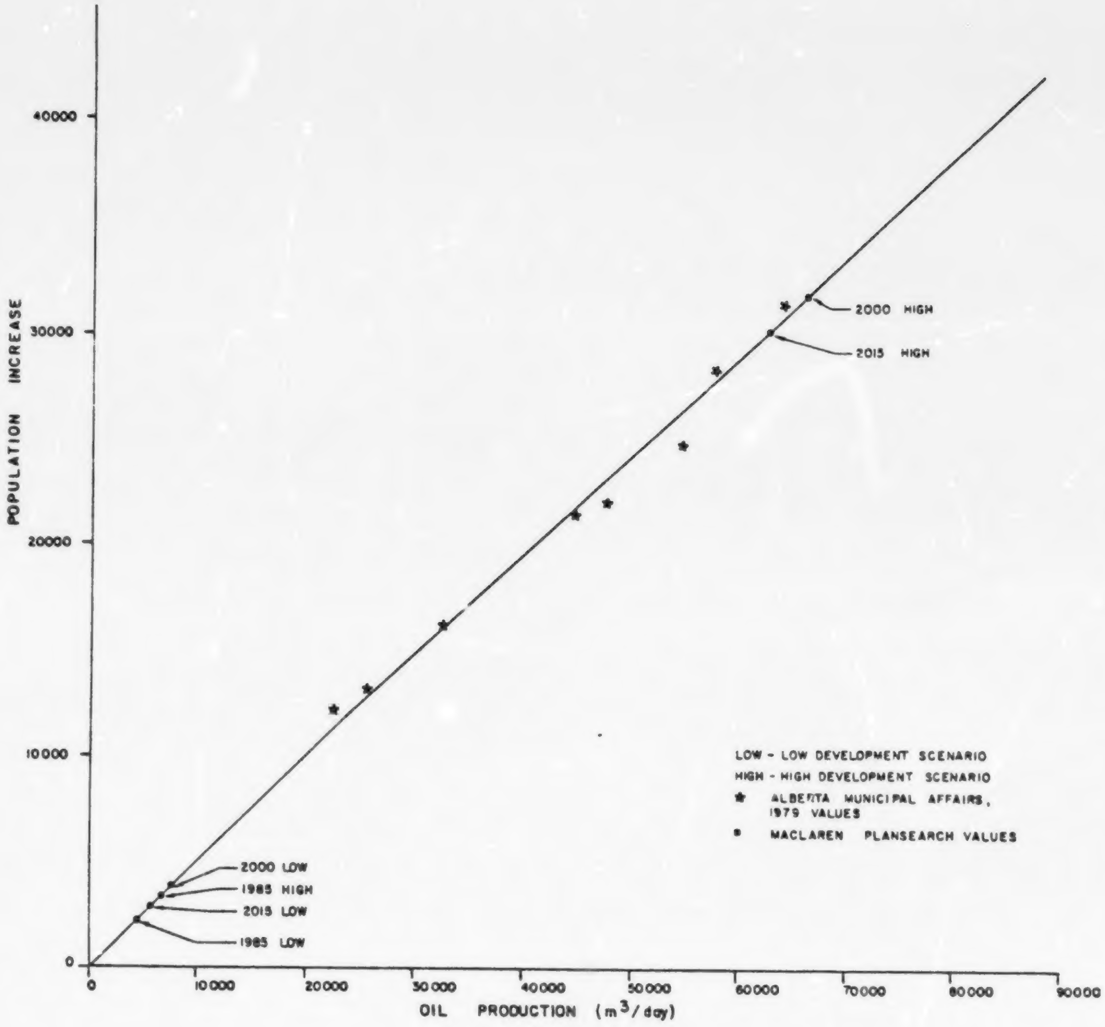


Figure 5.1

FUTURE OIL PRODUCTION
VS
POPULATION INCREASE
COLD LAKE AREA

Maclaren Plansearch

Population increases due to development were distributed differently. Alberta Municipal Affairs (1979) estimated that future increases would be distributed as follows:

Cold Lake	25% - 30%
Grand Centre	45% - 50%
Bonnyville	10% - 20%

This leaves a maximum of 20% of the population growth for the rural area including hamlets. This distribution was applied to the future population increases calculated in this study.

The population projections are summarized in Tables 5.2 and 5.3, one for low future development levels, and one for high future development levels. The total population of the basin could range for each year from:

1985	32,070	to	33,270	people
2000	52,250	to	80,350	people
2015	83,100	to	110,100	people

5.3 Water Quantity Demands

5.3.1 Domestic and Municipal

Water demands for domestic and municipal uses will increase as industrial development occurs and as the population increases. Water demand was calculated as the per capita demand in l/day multiplied by the population projected for that community or group for 1985, 2000 and 2015. A summary of future withdrawals and returns is found in Table 5.4. Details for each municipality are found in Appendix D. Surface water withdrawals would increase to 11,980 dam^3/yr while groundwater withdrawals would increase to 4870 dam^3/yr by 2015. Surface water returns would amount to 75-79 percent of surface water withdrawals, increasing to a maximum of 9,248 dam^3/yr.

TABLE 5.2

LOW POPULATION PROJECTIONS - BEAVER RIVER BASIN

	YEAR	PROJECTION OF EXISTING POPULATION	POPULATION INCREASE DUE TO INDUSTRIAL DEVELOPMENT	TOTAL
Ardmore- Fort Kent	1985	440	50	490
	2000	750	70	820
	2015	1,300	60	1,360
Bonnyville	1985	4,920	220	5,140
	2000	8,500	370	8,870
	2015	14,650	300	14,950
CFB Cold Lake	1985	5,500	0	5,500
	2000	6,500	0	6,500
	2015	7,500	0	7,500
Cold Lake-Grand Centre	1985	5,500	1,540	7,040
	2000	9,500	2,590	12,090
	2015	16,400	2,100	18,500
Glendon	1985	530	40	570
	2000	900	70	970
	2015	1,550	60	1,610
Indian Reserves	1985	2,950	0	2,950
	2000	5,100	0	5,100
	2015	8,800	0	8,800
Mallaig	1985	230	20	250
	2000	400	40	440
	2015	700	30	730
Rural	1985	9,800	330	10,130
	2000	16,900	560	17,460
	2015	29,200	450	29,650
TOTAL	1985	29,870	2,200	32,070
	2000	48,550	3,700	52,250
	2015	80,100	3,000	83,100

TABLE 5.3

HIGH POPULATION PROJECTIONS - BEAVER RIVER BASIN

	YEAR	PROJECTION OF EXISTING POPULATION	POPULATION INCREASE DUE TO INDUSTRIAL DEVELOPMENT	TOTAL
Ardmore - Fort Kent	1985	440	70	510
	2000	750	640	1,390
	2015	1,300	600	1,900
Bonnyville	1985	4,920	340	5,260
	2000	8,500	3,180	11,680
	2015	14,650	3,000	17,650
CFB Cold Lake	1985	5,500	0	5,500
	2000	6,500	0	6,500
	2015	7,500	0	7,500
Cold Lake-Grand Centre	1985	5,500	2,380	7,880
	2000	9,500	22,250	31,750
	2015	16,400	21,000	37,400
Glendon	1985	530	70	600
	2000	900	640	1,540
	2015	1,550	600	2,150
Indian Reserves	1985	2,950	0	2,950
	2000	5,100	0	5,100
	2015	8,800	0	8,800
Mallaig	1985	230	30	260
	2000	400	320	720
	2015	700	300	1,000
Rural	1985	9,800	510	10,310
	2000	16,900	4,770	21,670
	2015	29,200	4,500	33,700
TOTAL	1985	29,870	3,400	33,270
	2000	48,550	31,800	80,350
	2015	80,100	30,000	110,100

TABLE 5.4

SUMMARY OF FUTURE DOMESTIC AND MUNICIPAL WATER WITHDRAWALS AND RETURNS

		SURFACE WATER (dam^3/yr)				GROUND WATER (dam^3/yr)			
		WITHDRAWAL		RETURN		WITHDRAWAL		RETURN	
		LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
Domestic (Rural)	1985	-	-	-	-	1290	1320	-	-
	2000	-	-	-	-	2230	2770	-	-
	2015	-	-	-	-	3790	4300	-	-
Municipal	1985	3690	3840	2800	2928	150	160	-	-
	2000	5610	9320	4248	7320	260	420	-	-
	2015	8310	11980	6240	9248	440	570	-	-
TOTAL	1985	3690	3840	2800	2928	1440	1480	-	-
	2000	5610	9320	4248	7320	2490	3190	-	-
	2015	8310	11980	6240	9248	4230	4870	-	-

5.3.2 Irrigation

It is unlikely that irrigation will increase significantly in this area. Although agriculture is a major activity in the region, rainfall amounts are generally sufficient for pasture or grain crops. Since no projections of water use for this purpose in this area were available, an arbitrary 20 percent increase in water withdrawals was assumed to occur by 2000 and again by 2015 from surface water sources. Withdrawals would therefore amount to 325 dam^3/yr. in 1985; 390 dam^3/yr. in 2000; and 470 dam^3/yr. in 2015.

5.3.3 Industrial

A total of 14 oil companies indicated during interviews that they have plans for development in the study area. Water withdrawals and returns are summarized in Tables 5.5 to 5.7 by oil company. The withdrawal quantities were supplied by the company. Few companies had firm plans on their future water source during commercial operations. Since it is unlikely that the company could obtain sufficient groundwater to supply large size (or even the larger of the medium size) plants due to aquifer characteristics (Alberta Environment, Carlson, 1981), companies without definite plans were assumed to use surface water as a source. Most companies projecting the operation of medium sized plants (as defined in this study) expect to use deep well disposal for all effluents and have no surface water returns. However, since some of this effluent may be suitable for surface disposal (eg. ion exchange regenerant), Alberta Environment personnel (Johnston, 1981) recommended that for the pruposes of this study, the surface water disposal option be used for these effluents.

TABLE 5.5

OIL COMPANY WATER WITHDRAWALS AND RETURNS - 1985

	SURFACE WATER (dam^3/yr)				GROUND WATER (dam^3/yr)	
	WITHDRAWAL		RETURN		WITHDRAWAL	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
Amoco Canada	-	-	-	-	-	1160
BP Canada	-	-	0	66	1100	2190
Canada-Cities Service	-	-	-	0	-	410
Chevron Standard	90	550	0	0	-	-
Dome Petroleum	-	-	0	0	690	830
Esso Resources Canada	2000	2000	0	0	-	-
Gulf Canada Resources	-	350	-	0	-	-
Husky Oil (Alberta)	-	-	-	0	-	165
Mobil Oil Canada	2	290	0	0	-	-
Murphy Oil	310	530	0	0	-	-
Norcen Energy Resources	-	-	0	0	140	140
Petro Canada Exploration	250	280	0	0	-	-
Suncor Resources Group	1040	1040	0	0	-	-
Union Texas of Canada	-	-	0	0	130	180
TOTAL	3692	5040	0	66	2060	5075

TABLE 5.6

OIL COMPANY WATER WITHDRAWALS AND RETURNS - 2000

	SURFACE WATER (dam^3/yr)				GROUND WATER (dam^3/yr)	
	WITHDRAWAL		RETURN		WITHDRAWAL	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
Amoco Canada	-	-	-	139	-	2320
BP Canada	-	-	66	263	2190	2190
Canada-Cities Service	-	-	0	45	410	750
Chevron Standard	-	1100	-	66	-	-
Dome Petroleum	-	7150	-	0	-	-
Esso Resources Canada	2000	23900	0	1500	-	-
Gulf Canada Resources	-	1020	-	61	-	-
Husky Oil (Alberta)	-	1220	-	73	-	-
Mobil Oil Canada	580	2180	0	131	-	-
Murphy Oil	740	1500	44	90	-	-
Norcen Energy Resources	-	1740	28	104	460	-
Petro Canada Exploration	250	1190	0	71	-	-
Suncor Resources Group	1740	3480	105	210	-	-
Union Texas of Canada	-	730	0	0	130	-
TOTAL	5310	45210	243	2753	3190	5260

TABLE 5.7

OIL COMPANY WATER WITHDRAWALS AND RETURNS - 2015

	SURFACE WATER (dam^3/yr)				GROUND WATER (dam^3/yr)	
	WITHDRAWAL		RETURN		WITHDRAWAL	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
Amoco Canada	-	-	-	-	-	-
BP Canada	-	-	66	263	2190	2190
Canada-Cities Service	-	-	-	45	-	750
Chevron Standard	-	1100	-	66	-	-
Dome Petroleum	-	7150	-	0	-	-
Esso Resources Canada	2000	23900	0	1500	-	-
Gulf Canada Resources	-	1020	-	61	-	-
Husky Oil (Alberta)	-	1220	-	73	-	-
Mobil Oil Canada	-	2180	-	131	-	-
Murphy Oil	2200	4500	132	270	-	-
Norcen Energy Resources	-	1740	28	104	460	-
Petro Canada Exploration	-	640	-	38	-	-
Suncor Resources Group	-	-	-	-	-	-
Union Texas of Canada	-	730	0	0	130	-
TOTAL	4200	44180	226	2551	2780	2940

This issue was discussed in Section 3.4. Appendix E contains details for each company regarding current and future withdrawals and returns, water sources, and assumptions made in the calculations.

Surface water withdrawals by the oil companies would increase under the low development scenario from 3692 dam^3/yr in 1985 to 5300 dam^3/yr in 2000. Withdrawals would then decrease to 4200 dam^3/yr in 2015, as pilot plant operations closed. Under the high development scenario, surface water withdrawals would increase from 5040 dam^3/yr in 1985 to 45,210 dam^3/yr in 2000, then decline to 44,180 dam^3/yr in 2015. Groundwater withdrawals would remain low (below 5260 dam^3/yr). Surface water return flows would amount to 0-5.4 percent of total withdrawals (0 to 2753 dam^3 yr).

5.3.4 Other

It is possible that allocations of water for "other" uses will be made in the future. The most likely large user would be Ducks Unlimited who have an interest in developing marshes in the area for waterfowl propagation. Ducks Unlimited was contacted (Christianson, 1981) regarding their future plans in the Beaver River basin. These potential and proposed projects are listed in Appendix F. All of their projects would lower or maintain water levels in the water body. The losses through evaporation for these projects would therefore be approximately the same or lower than evaporation presently occurring from these water bodies. For this reason, future demand for this purpose were considered insignificant and were ignored.

5.3.5 Non-Consumptive Uses

No forecasts of water use for the non-consumptive users of storage and diversion were made. This water is not withdrawn for use, but rather is redirected or stored temporarily. Some changes in stream flow regime may occur.

EFFECTS OF WATER SHORTAGE

6.0 EFFECTS OF WATER SHORTAGE

The water balance model that will be run using data from this report requires the assignment of penalty values to ranges of water use for each purpose. The penalty system helps in allocation of a scarce resource (the water) between the contending users. This discussion is intended to be used as guidance in the assignment of their penalty values. The impacts of cut-backs in water supply to each category of user is discussed.

Domestic

Domestic water supplies are usually taken from groundwater. Under drought conditions, the level of groundwater in each well may decline. Water shortages may be forced upon the user if the well does not produce the anticipated supply. Cut-backs in use would be totally voluntary since licences are not held under the Water Resources Act. Conservation measures such as cutting back on lawn and garden watering and car washing could be instituted without undue hardship, until water levels recover.

Municipal

Municipalities could adjust water demands to a lower level by cutting back individual use in a similar manner to domestic users. Overall conservation of water within the home has been generally accepted as viable. Cut-backs could be voluntary or enforced.

Industrial

Industrial water users may be in a more difficult position if water shortages occur. The effect of an imposed water shortage on the in-situ heavy oil extraction process would be serious both in terms of economics and in terms of problems with the process of extracting the oil from the formation itself. Under all three oil recovery processes, a 10 percent reduction in water supply would merely cut production proportionally. A 30 percent reduction would be more serious. Under the steam stimulation or in-situ burning processes, the operator would likely close a third of the injection wells temporarily. There would be a general cooling of the formation in the closed wells and time would be needed to re-heat the formation after water again became available. In the case of the steam drive process, a water shortage would likely be met by injecting steam at a reduced rate to all wells in order to keep the oil moving throughout the formation.

The time duration associated with a water shortage would be critical. A one month shortage would have a proportionally smaller effect than a six month shortage as the formation would cool off much less. Re-heating of the formation would take time and cause significant cut-backs in production.

The problems that water shortages imply are difficult ones to answer definitively. Water quantities, water qualities, and economics must be combined in order to assess the basin-wide implications of shortages. That task may be undertaken in the future when all components of the Beaver River Study are completed, and evaluation of the results is undertaken.

CONCLUSIONS

7.0 CONCLUSIONS

Withdrawal water demands from the Beaver River could increase significantly from current levels to 1985, 2000 and 2015 levels. Demands would originate largely from industrial purposes. Domestic and municipal uses will increase as well.

A large portion of the current population lives in the Cold Lake - Grand Centre area and in Bonnyville. Both towns are increasing the capacities of their water supply and/or sewage treatment facilities for the projected increase in population. Other towns have rather small, unsophisticated water use systems.

In-situ heavy oil extraction plants will generally use a steam stimulation or steam drive system. In either system, steam is injected into the oil bearing formation until the oil becomes fluid, then the oil is pumped out. Water that is pumped up with the oil will be disposed of in deep injection wells. Blowdown and backwash waters from the surface operations will be discharged to surface waters.

Currently, domestic and municipal demands make up 64 percent of the total water withdrawals (6510 dam^3/yr). Industrial uses make up 31 percent, and irrigation, 5 percent of the remainder. Irrigation withdrawals are seasonal. Of total surface and groundwater withdrawals, 37 percent (2380 dam^3/yr) is returned to surface water bodies. All surplus industrial process water is deep well injected.

Future water demands will depend on the level of industrial development that occurs. Low and high development scenarios were developed based on information obtained from the oil companies. Heavy oil production could increase from the current level of 2000 m^3/day to 4272-6865 m^3/day in 1985; 7320-66,100 m^3/day in 2000; and 6590-62,600 m^3/day in 2015.

Population projections were made based on the projected industrial development. The base population of the basin was seen to increase naturally from the current 26,560 people to 80,100 by 2015 (without industrial development). Industrial development could add to those figures 2200 - 3400 people by 1985; 3700 - 31,800 people by 2000; and 3000 - 30,000 people by 2015.

Current and future water withdrawals and returns associated with increases in industrial development and population are summarized in Table 7.1 and presented graphically in Figure 7.1. Industrial demands would make up a larger proportion of the total withdrawals, increasing up to 50,470 dam^3/yr surface water and groundwater or 82 percent of the total withdrawals. Domestic and Municipal withdrawals would increase up to four times the current rate to 16,850 dam^3/yr. Irrigation withdrawals would remain at insignificant levels (4 percent of the total withdrawal). Even at the maximum net withdrawal in 2015 of 43,068 dam^3/yr , obligations to Saskatchewan under the Master Apportionment Agreement (Canada, P.C., 1969) would be easily met for the lowest recorded annual flow of 241,000 dam^3/yr.

Data from this report will be used in a water balance model that will assess whether conflicts between water supply and demand will occur in the future. These water volumes will also be input to a water quality model that will analyze the Beaver River system for possible water quality problems in the future.

TABLE 7.1

SUMMARY OF CURRENT AND FUTURE WATER WITHDRAWALS AND RETURNS BY PURPOSE - BEAVER RIVER BASIN

		SURFACE WATER (dam^3/yr)				GROUNDWATER (dam^3/yr)			
		WITHDRAWAL		RETURN		WITHDRAWAL		RETURN	
		LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
Domestic (Rural)	1980	110*		40*		1010*		-	-
	1985	-	-	-	-	1290	1320	-	-
	2000	-	-	-	-	2230	2770	-	-
	2015	-	-	-	-	3790	4300	-	-
Municipal	1980	3010*		2340		50*		-	-
	1985	3690	3840	2800	2930	150	160	-	-
	2000	5610	9320	4250	7320	260	420	-	-
	2015	8310	11980	6240	9250	440	570	-	-
Irrigation	1980	320*		-	-	-	-	-	-
	1985	325	325	-	-	-	-	-	-
	2000	390	390	-	-	-	-	-	-
	2015	470	470	-	-	-	-	-	-
Industrial	1980	1320*		-	-	690*		-	-
	1985	3692	5040	0	66	2060	5075	-	-
	2000	5310	45210	243	2753	3190	5260	-	-
	2015	4200	44180	226	2551	2780	2940	-	-
Total	1980	4760*		2380*		1750*		-	-
	1985	7707	9205	2800	2996	3500	6555	-	-
	2000	11310	54920	4493	10073	5680	8450	-	-
	2015	12980	56830	6466	11801	7010	7810	-	-

* current figures

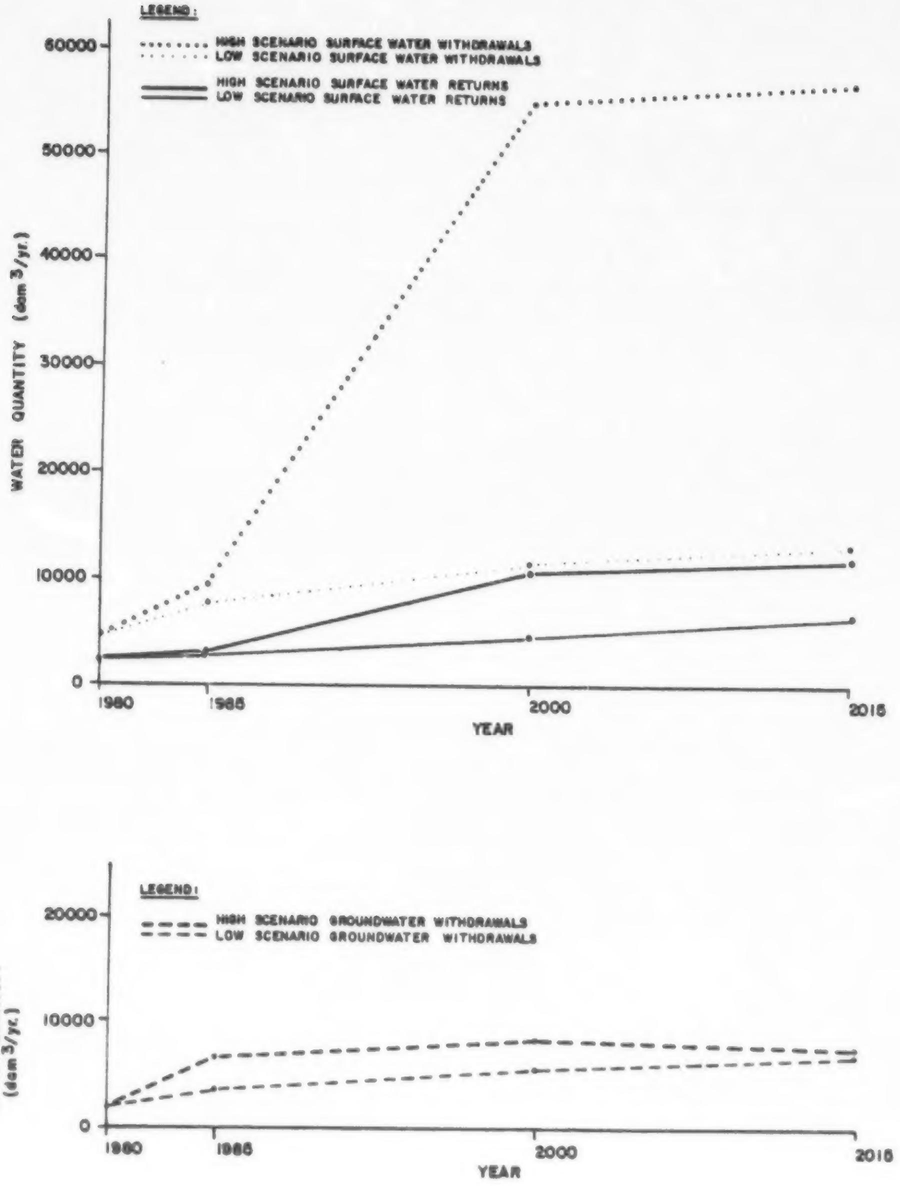


Figure 7.1

CURRENT AND FUTURE WATER WITHDRAWALS AND RETURNS — BEAVER RIVER BASIN

MacLaren Plansearch

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8.0 REFERENCES

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APPENDIX A

ACTIVE, AUTHORIZED OR LICENCED WATER PROJECTS IN THE BEAVER RIVER BASIN

(supplied by Surface Water Rights Branch, Alberta Environment, 1981).

Licences are sequenced by statutory purpose.

TABLE LEGEND

STAT PURP -	Statutory purpose as defined in the Water Resources Act DOM - domestic MUN - municipal IRR - irrigation IND - industrial OTHR- other STOR- storage DIV - diversion
UNIQUE NUMBER -	priority date (year, month, day, application number that day).
FILE NO. -	Water Rights Branch internal file number.
LAND LOCATION -	legal land description.
WSC BASIN -	Water Survey of Canada river basin notation.
SOURCE SUPPLY -	source of water supply.
SOURCE IS TRIBUTARY TO -	water body that the source is tributary to.
ANNUAL QTY -	authorized or licenced quantity of water in acre-feet/yr.
DATE AUTHORIZED -	date of approval for construction of the project and authorization to operate the project until a a licence is issued.
DATE LICENCED -	date licenced to operate the project.
STAT -	status of file A - active

JUL 29, 1981

ALL ACTIVE PROJECTS IN BEAVER RIVER
BASIN (WSCBASIN 06FA-06AF,06BA)
SEQUENCED BY STAT. PURP

STAT PURP	UNIQUE NUMBER	FILE NO.	LAND LOCATION	WSC BASIN	SOURCE SUPPLY	SOURCE IS TRIBUTARY TO	ANNUAL QTY	DATE AUTHORIZD	DATE LICENSED	STAT
DOM	1960-02-19-03	10216	SW16-062-10-4	06AA	COULEE 97	BEAVER RIVER	0,000,005	/ /	/ /	A
DOM	1969-01-08-01	12596	NW24-060-07-4	06AC	COULEE 3	MOOSE LAKE X	0,000,002	69/03/19	69/05/15	A
DOM	1969-07-09-04	12731	SW09-064-11-4	06AA	COULEE 1 5	FORK LAKE	0,000,003	69/09/19	69/11/17	A
DOM	1969-11-28-04	12958	NE07-064-13-4	06AA	COULEE 1 6	DESMAW LAKEX	0,000,002	70/04/13	71/11/23	A
DOM	1981-03-25-01	14660	SE22-066-17-4		COULEE	LOFTY LAKE	1			
MUN	1950-08-09-02	8735	SW15-061-06-4	06AC	MOOSE LAKE	MOOSELAKE RI	0,000,500	66/07/05	75/11/04	A
MUN	1951-01-15-02	9029	NW24-063-02-4	06AF	COLD LAKE	BEAVER RIVER	0,000,935	78/04/28	/ /	A
MUN	1968-03-29-01	12367	NW12-065-19-4		SKELETON LA	AMISK LAKE	90	69/07/02		
MUN	1973-02-14-01	15190	SW06-059-06-4	06AA	KEHEWIN LAKE	MURIEL LAKE	0,000,040	73/05/29	74/11/04	A
MUN	1975-12-18-01	17473	SE28-060-10-4	06AD	DENNING LAKE	BEAVER RIVER	0,000,011	76/04/07	/ /	A
MUN	1978-01-16-01	18450	NW04-063-02-4	06AF	COLD LAKE	BEAVER RIVER	0,001,715	78/04/07	/ /	A
MUN	1979-04-25-01	17888	0832-061-04-4	06AC	AQUIFER	MURIEL CREEK	0,000,041	79/06/07	/ /	A
MUN	1979-09-06-02	19473	SW25-063-02-4	06AF	COLD LAKE	COLD RIVER	, ,	/ /	/ /	A
MUN	1980-10-01-01	11674	NE15-061-03-4	06AA	MINNIE LAKE	COLUMBINE CR	, ,	/ /	/ /	A
MUN	1980-10-23-01	8735	SW15-061-06-4	06AC	MOOSE LAKE	MOOSE RIVER	0,000,130	81/04/08	81/04/08	A
IRR	1967-02-06-02	12211	SE11-061-06-4	06AC	SLOUGH 1	MOOSE LAKE	0,000,035	67/06/13	68/05/14	A
IRR	1967-02-07-01	12210	NW11-061-06-4	06AC	SLOUGH 1	MOOSE LAKE	0,000,033	67/10/06	68/05/09	A
IRR	1968-04-23-01	12382	SE04-060-07-4	06AC	SLOUGH 1 1	BANGS LAKE	0,000,050	68/10/31	69/01/21	A
IRR	1968-05-03-01	12381	SW32-060-02-4	06AD	SLOUGH 1 2	REDSPRING CR	0,000,035	68/10/31	75/12/12	A
IRR	1969-02-10-02	12617	SE13-065-17-4	06AA	SLOUGH 1 4	AMISK RIVER	0,000,055	69/07/04	/ /	A
IRR	1972-04-06-02	13945	NW34-064-17-4	06AA	SLOUGH	AMISK CREEK	0,000,030	72/10/19	/ /	A
IRR	1979-06-08-01	19300	SW10-061-05-4	06AC	CHARLOTTE LA	MURIEL CREEK	0,000,025	80/03/11	/ /	A
IND	1915-09-10-02	796	SE13-066-15-4	06AA	MISSAWAWI LA	ATHABASCA RI	0,000,073	15/12/23	17/06/27	A
IND	1931-03-13-01	2133	SE20-061-06-4	06AC	MOOSE LAKE	MOOSELAKE RI	0,000,101	31/05/13	32/08/18	A
IND	1965-01-26-01	11861	NE15-064-03-4	06AC	ETHEL LAKE	MARIE CREEK	0,000,350	65/03/16	69/11/03	A
IND	1973-07-06-02	15572	SW18-058-04-4	06AC	LAKE	BLUET LAKE	0,000,094	73/11/02	75/10/16	A
IND	1973-10-01-02	15356	NE15-064-03-4	06AC	ETHEL LAKE	COLD LAKE	0,000,900	78/02/21	76/04/02	A
IND	1975-02-04-02	15725	1320-062-03-4	06AC	AQUIFER	BEAVER RIVER	0,000,048	75/09/05	/ /	A
IND	1975-02-04-03	15725	1420-062-03-4	06AC	AQUIFER	BEAVER RIVER	0,000,048	75/09/05	/ /	A
IND	1976-03-09-01	17584	NW12-065-02-4	06AC	COLD LAKE	BEAVER RIVER	0,002,200	76/10/04	/ /	A
IND	1976-05-07-02	17667	SE36-061-02-4	06AD	BEAVER RIVER	CHURCHILL RI	0,000,140	77/06/07	78/11/30	A

ALL ACTIVE PROJECTS IN BEAVER RIVER
BASIN (WSCBASIN 06FA-06AF,06BA)
SEQUENCED BY STAT. PURP

STAT PURP	UNIQUE NUMBER	FILE NO.	LAND LOCATION	WSC BASIN	SOURCE SUPPLY	SOURCE IS TRIBUTARY TO	ANNUAL QTY	DATE AUTHORIZD	DATE LICENSED	STAT
IND	1976-05-26-01	16926	NW24-065-02-4	06AC	AQUIFER	MEDLEY RIVER	0,000,325	76/07/20	/ /	A
IND	1976-05-26-02	16926	NW24-065-02-4	06AC	AQUIFER	MEDLEY RIVER	0,000,325	76/07/20	/ /	A
IND	1977-03-09-01	17842	NI 07-066-05-4	06AB	AQUIFER	WOLF RIVER	0,000,382	77/04/29	/ /	A
IND	1977-03-09-12	17842	NE07-066-05-4	06AB	AQUIFER	WOLF RIVER	0,000,NIL	77/04/29	/ /	A
IND	1978-03-08-02	16943	0328-061-04-4	06AC	AQUIFER	MURIEL CREEK	0,000,270	78/10/25	/ /	A
IND	1978-08-11-03	18400	W021-064-02-4	06AF	COLD LAKE	BEAVER RIVER	, ,	/ /	/ /	A
IND	1979-09-06-03	19453	SE24-059-05-4	06AC	MURIEL LAKE	LANDRY LAKE	0,000,500	80/09/08	/ /	A
IND	1980-02-29-01	15725	1320-062-03-4	06AC	AQUIFER	BEAVER RIVER	0,000,072	80/06/03	/ /	A
IND	1980-02-29-02	15725	1420-062-03-4	06AC	AQUIFER	BEAVER RIVER	0,000,072	80/06/03	/ /	A
IND	1980-08-08-01	16943	0228-061-04-4	06AC	AQUIFER	MURIEL CREEK	0,000,NIL	/ /	/ /	A
IND	1980-09-09-01	19260	0604-063-08-4	06AA	AQUIFER	BEAVER RIVER	, ,	/ /	/ /	A
IND	1980-09-22-01	19931	SW10-061-05-4	06AC	SLOUGH	CHARLOTTE L	, ,	/ /	/ /	A
IND	1981-03-03-01	19310	0224-061-05-4	06AC	AQUIFER	MURIEL CREEK	0,000,001	81/04/07	/ /	A
IND	1981-04-08-01	14542	0613-063-08-4	06AB	AQUIFER	SAND RIVER	, ,	/ /	/ /	A
OTHR	1926-03-13-01	1833	SE01-065-03-4	06AC	MARIE LAKE	COLD LAKE	0,000,100	28/05/02	30/04/08	A
OTHR	1937-07-29-02	3732	NE13-066-14-4	06AA	BEAVER RIVER	CHURCHILL RI	0,000,010	37/10/05	/ /	A
OTHR	1944-05-10-02	6966	0003-066-13-4	06AA	CROSS LAKE	BEAVER LAKE	, ,	/ /	/ /	A
OTHR	1947-03-06-01	7565	SW29-064-17-4	06AA	AMISK RIVER	BEAVER RIVER	0,000,NIL	/ /	/ /	A
OTHR	1950-10-10-06	8735	NE34-061-07-4	06AC	YELLING CREE	MOOSELAKE RI	, ,	/ /	/ /	A
OTHR	1953-01-07-02	14097	SE14-064-05-4	06AC	TUCKER LAKE	JACKFISH CRE	, ,	/ /	/ /	A
OTHR	1953-01-07-03	14098	NW12-064-04-4	06AC	MOORE LAKE	HILDA LAKE	, ,	/ /	/ /	A
OTHR	1953-04-30-01	14071	NE27-062-13-4	06AA	WHITEFISH CR	WHITEFISH LA	0,007,055	53/05/15	/ /	A
OTHR	1953-07-21-01	14084	SW33-061-12-4	06AA	CREEK 95	BUNDER LAKE	0,001,000	70/04/10	/ /	A
OTHR	1953-07-21-02	14086	NE08-061-11-4	06AA	CREEK 96	NORBERG LAKE	0,001,000	70/04/10	/ /	A
OTHR	1971-04-26-01	13196	SW15-065-02-5		MEDLEY R	BEAVER R	8			
STOR	1974-01-18-01	19933	1314-063-11-4	06AA	FORK LAKE	BEAVER RIVER	0,000,NIL	78/05/11	/ /	A
STOR	1975-09-15-01	13404	SE13-063-03-4	06AC	MALONEY LAKE	BEAVER RIVER	0,000,NIL	76/07/27	/ /	A
STOR	1976-08-12-02	17802	SE08-061-05-4	06AC	JESSIE LAKE	MURIEL CREEK	0,000,NIL	76/10/18	80/03/27	A
STOR	1977-09-26-02	18314	SE14-061-05-4	06AC	CHARLOTTE LA	MURIEL CREEK	0,000,NIL	78/08/22	/ /	A
STOR	1979-05-23-04	19265	SW07-064-03-4	06AC	SLOUGH	HILDA LAKE	0,000,NIL	79/12/06	/ /	A
STOR	1979-11-26-02	19512	NW12-064-03-4	06AC	MARIE CREEK	BEAVER RIVER	0,000,NIL	80/02/14	/ /	A

JUL 29, 1981

ALL ACTIVE PROJECTS IN BEAVER RIVER
BASIN (WSCBASIN 06FA-06AF,06DA)
SEQUENCED BY STAT. PURP

STAT PURP	UNIQUE NUMBER	FILE NO.	LAND LOCATION	WSC BASIN	SOURCE SUPPLY	SOURCE IS TRIBUTARY TO	ANNUAL QTY	DATE AUTHORIZD	DATE LICENSED	STAT
DIV	1916-10-11-01	847	0016-063-05-4	06AC		JACKFISH CRE	, ,	/ /	/ /	A
DIV	1918-05-16-01	892	SW05-061-10-4	06AA	CREEK	GRASSY IS LA	0,000,NIL	22/03/02	/ /	A
DIV	1920-08-17-01	1595	SW05-061-10-4	06AA	CREEK	GRASSY IS LA	, ,	/ /	/ /	A
DIV	1922-06-14-01	1681	NW26-065-12-4	06AA	BEAVER LAKE	BEAVER RIVER	, ,	24/07/25	/ /	A
DIV	1923-02-03-01	1690	NE29-061-11-4	06AA	COULEE	NORBERG LAKE	0,000,NIL	24/01/07	/ /	A
DIV	1958-10-21-01	1639	SW03-063-02-4	06AC	FONTAINE LAK	MARIE CREEK	0,000,NIL	58/11/03	/ /	A
DIV	1960-07-26-02	12725	SE24-063-07-4	06AC	MANATOKAN LA	MANATOKAN CR	0,000,NIL	62/08/06	/ /	A
DIV	1960-10-07-01	13003	SE19-061-06-4	06AC	MOOSE LAKE	MOOSELAKE RI	0,000,NIL	63/10/30	/ /	A
DIV	1960-11-29-01	12630	SW24-063-02-4	06AC	MEDLEY RIVER	COLD LAKE X	0,000,NIL	61/03/17	/ /	A
DIV	1963-09-03-01	12716	NE35-059-03-4	06AD	COULEE	ANGLING LAKE	, ,	/ /	/ /	A
DIV	1963-09-03-02	12716	SE01-061-03-4	06AD	COULEE	REITA CREEK	, ,	/ /	/ /	A
DIV	1964-09-21-02	13004	SE16-061-07-4	06AC	MOOSE LAKE	MOOSELAKE RI	0,000,NIL	64/10/02	/ /	A
DIV	1966-01-17-03	12714	NE02-061-08-4	06AC	COULEE	THINLAKE RIV	0,000,NIL	67/11/09	/ /	A
DIV	1966-07-29-06	847	SW22-063-05-4	06AC	JACKFISH CRE	BEAVER RIVER	0,000,NIL	66/09/27	/ /	A
DIV	1966-07-29-07	847	NE06-063-05-4	06AC	JACKFISH CRE	BEAVER RIVER	0,000,NIL	66/09/27	/ /	A
DIV	1967-11-20-03	12463	NE09-062-03-4	06AC	MURIEL CREEK	BEAVER RIVER	0,000,NIL	68/09/09	/ /	A
DIV	1968-08-28-04	19664	SW26-062-05-4	06AC	BEAVER RIVER	CHURCHILL RI	0,000,NIL	69/09/10	/ /	A
DIV	1972-06-19-03	14340	SE21-063-06-4	06AC	SLOUGH	CHURCHILL RI	, ,	/ /	/ /	A
DIV	1975-03-20-10	17066	SW11-061-09-4	06AA	SLOUGH	COLUMBINE CR	0,000,NIL	75/05/14	81/01/09	A
DIV	1975-05-15-04	16998	SW19-062-05-4	06AC	COULEE	BEAVER RIVER	0,000,NIL	75/07/17	76/03/30	A
DIV	1975-10-20-02	17375	SW29-063-05-4	06AC	COULEE	JACKFISH CRE	0,000,NIL	76/05/14	81/01/09	A
DIV	1976-05-18-01	16487	SE03-063-02-4	06AF	AQUIFER	MARIE CREEK	0,000,175	76/11/22	/ /	A
DIV	1976-09-07-01	17790	NW11-061-06-4	06AC	SURFACE RUNO	MOOSELAKE RI	0,000,NIL	76/10/19	78/12/12	A
DIV	1978-07-25-13	19592	NW15-061-10-4	06AA	GRASSY IS LA	ST LINA CREE	0,000,NIL	80/01/08	81/03/05	A
DIV	1978-08-11-02	847	SW05-063-05-4	06AC	SLOUGH	JACKFISH CRE	0,000,NIL	78/12/19	/ /	A
DIV	1979-01-22-02	19062	NW13-063-02-4	06AC	SURFACE RUNO	MARIE CREEK	0,000,NIL	79/12/19	/ /	A
DIV	1979-08-30-01	19314	SE12-063-03-4	06AC	MARIE CREEK	BEAVER RIVER	0,000,NIL	80/01/23	/ /	A
DIV	1979-09-05-03	1639	NE33-062-02-4	06AC	SURFACE RUNO	MARIE CREEK	0,000,NIL	80/03/21	/ /	A
DIV	1980-07-18-01	43169	SE11-061-06-4	06AC	COULEE	MOOSE LAKE	0,000,NIL	80/09/25	/ /	A
DIV	1980-12-11-01	43063	SE14-061-05-4	06AC	CHARLOTTE LA	MURIEL CREEK	0,000,NIL	81/04/28	/ /	A

APPENDIX B

ACTIVE AUTHORIZED OR LICENCED WATER PROJECTS WITHIN DESIGNATED REACHES

Each active authorization or licence located within each designated reach is noted. Licences are grouped by source (surface water or groundwater), and are ranked within each source by purpose and unique number. Highest priority uses are, therefore, listed first, and lowest priority uses last. Withdrawals and returns are quantified for 1980 and for the ultimate (probable upper limit of return) allowed under the licence.

REACH NO. 132					WITHDRAWALS (dam³/yr)		RETURNS (dam³/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
SURFACE WATER									
	OTHER								
13196	Dept. of Lands & Forest, Fish & Wildlife Div.	1971-04-26-01	SW15-65-02-5	Medley R.	9.9	9.9	9.9	9.9	fish propagation
					TOTAL 9.9	9.9	9.9	9.9	
GROUND WATER									
	INDUSTRIAL								
16926	Norcen Energy Resources	1976-05-26-01	NW24-65-02-4	aquifer	400.9	116.0[a]	0	0	injection
16926	Norcen Energy Resources	1976-05-26-02	NW24-65-02-4	aquifer	400.9	23.4[a]	0	0	injection-standby
					TOTAL 801.8	139.4	0	0	

[a] 1979 figures

REACH NO. 206					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
SURFACE WATER									
	no licences								
GROUND WATER									
	INDUSTRIAL								
17842	BP Exploration Canada	1977-03-09-01	NE07-66-05-4	aquifer	471.2	159.0[a]	0	0	injection
17842	BP Exploration Canada	1977-03-09-12	NE07-66-05-4	aquifer	NIL	30.8	NIL	0	injection-standby
				TOTAL	471.2	189.8	0	0	

[a] 1979 figures

REACH NO. 210					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
SURFACE WATER									
	DOMESTIC								
12596	Smith, D.M. & K.	1969-01-08-01	NW24-60-07-4	Coulee 13	2.5	2.5	0	0	stockwatering
	MUNICIPAL								
8735[a]	Town of Bonnyville	1950-08-09-02	SW15-61-06-4	Moose L.	616.7[b]	629.1	-	-	urban supply
15190	Gov't of Canada	1973-02-14-01	SW06-59-06-4	Kehewin L.	49.3	55.1	39.4	19.2	community supply
11674	Village of Glendon	1980-10-01-01	NE15-61-08-4	Minnie L.	95.0[c][r]	70.8	76.0	56.2	urban supply
8735[a]	Town of Bonnyville	1980-10-23-01	SW15-61-06-4	Moose L.	160.4	171.2	—	–	urban supply
	IRRIGATION								
12211	Vincent, Marcel G.	1967-02-06-02	SE11-61-06-4	slough 1	43.2	43.2	0	0	35 acres
12210	Turcotte, Rene J.	1967-02-07-01	NW11-61-06-4	slough 1	40.7	40.7	0	0	33 acres
12382	Dargis, A. Michel	1968-04-23-01	SE04-60-07-4	slough 11	61.7	61.7	0	0	73 acres
	INDUSTRIAL								
2133	Canadian Nat'l Rwy	1931-03-13-01	SE20-61-06-4	Moose L.	124.6	0	0	0	steam trains
	DIVERSION								
13003	M.D. Bonnyville	1960-10-07-01	SE19-61-06-4	Moose L.	NIL	0	0	0	Anshaw Dr. L. flood control
13004	M.D. Bonnyville	1964-09-21-02	SE16-61-07-4	Moose L.	NIL	0	0	0	Franchere flood control
12714	M.D. Bonnyville	1966-01-17-03	NE02-61-08-4	coulee	NIL	0	0	0	Minnie L. flood control
17790	M.D. Bonnyville	1976-09-07-01	NW11-61-06-4	surface runoff	NIL	0	0	0	Vincent flood control
43169	Six-Vee Enterprises	1980-07-18-01	SE11-61-06-4	coulee	NIL	0	0	0	drainage
					TOTAL 1194.1	1074.3	115.4	75.4	
GROUNDWATER									
	no licences								

[a] double entry; also in Reach 224; water is withdrawn in Reach 210, returned in Reach 224.
[b] application made for 3182 x $1000m^3/yr$ in 1981
[c] Glendon is converting to groundwater in 1981
[r] requested

REACH NO. 212

FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	WITHDRAWALS (dam^3/yr) AUTHORIZED OR LICENCED	1980	RETURNS (dam^3/yr) ULTIMATE	1980	COMMENTS
SURFACE WATER									
	DIVERSION								
12725	M.D. Bonnyville	1960-07-26-02	SE24-63-07-4	Manatokan L.	NIL	0	0	0	Manatokan L. flood control
14340	M.D. Bonnyville	1972-06-19-03	SE21-63-06-4	slough	NIL	0	0	0	drainage
				TOTAL	NIL	0	0	0	
GROUND WATER									
	no licences								

REACH NO. 216					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
	SURFACE WATER								
	OTHER								
14097	Ducks Unlimited	1953-01-07-02	SE14-64-05-4	Tucker L.	NIL[r]	0	0	0	waterfowl propagation
				TOTAL	NIL	0	0	0	
	GROUND WATER								
	no licences								

[r] requested

REACH NO. 221					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
SURFACE WATER									
	INDUSTRIAL								
11861	Imperial Oil Ltd.	1965-01-26-01	NE15-64-03-4	Ethel L.	431.7	236.8	0	0	injection-May Pilot
15356	Imperial Oil Ltd.	1973-10-01-02	NE15-64-03-4	Ethel L.	1110.1	1042.3	0	0	injection-Leming Pilot
	OTHER								
1833	Kopp, Elizabeth	1926-03-13-01	SE01-65-03-4	Marie L.	123.4	0	0	0	fur farming reserve
14098	Ducks Unlimited	1953-01-07-03	NW12-64-04-4	Moore L.	0[r]	0	0	0	waterfowl propagation
	STORAGE								
19265	Ducks Unlimited	1979-05-23-04	SW07-64-03-4	slough	NIL	0	0	0	lake stabilization
19512	Esso Resources Canada Ltd.	1979-11-26-02	NW12-64-03-4	Marie Cr.	NIL	0	0	0	lake stabilization
				TOTAL	1665.2	1279.1	0	0	
GROUNDWATER									
	no licences								

[r] requested

REACH NO. 223					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
SURFACE WATER									
	INDUSTRIAL								
15572	Murphy Oil Co. Ltd.	1973-07-06-02	SW18-58-04-4	lake	116.0	45.6	0	0	injection
19453	Petro Canada Exp. Inc.	1979-09-06-03	SE24-59-05-4	Muriel L.	616.7	0	0	0	injection start-up
				TOTAL	732.7	45.6	0	0	
GROUND WATER									
	no licences								

REACH NO. 224

FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	WITHDRAWALS (dam^3/yr) AUTHORIZED OR LICENCED	WITHDRAWALS (dam^3/yr) 1980	RETURNS (dam^3/yr) ULTIMATE	RETURNS (dam^3/yr) 1980	COMMENTS
SURFACE WATER									
	IRRIGATION								
19300	Kettner, Elwin R.	1979-06-08-01	SW10-61-05-4	Charlotte L.	30.8	30.8	0	0	30 acres
	MUNICIPAL								
8735A[a]	Town of Bonnyville	1950-08-09-02	SW15-61-06-4	Moose L.	-	-	493.4	503.3	urban supply
8735	Town of Bonnyville	1980-10-23-01	SW15-61-06-4	Moose L.	-	-	128.3	138.2	
	INDUSTRIAL								
19931	Suncor Inc.	1980-09-22-1	SW10-61-05-4	slough(sewage lagoon)	3441.4	0[b]	0	0	injection
	STORAGE								
17802	Town of Bonnyville	1976-08-12-02	SE08-61-05-4	Jessie L.	NIL	0	0	0	lake stabilization
18314	M.D. Bonnyville	1977-09-26-02	SE14-61-05-4	Charlotte L.	NIL	0	0	0	lake stabilization
	DIVERSION								
43063	Town of Bonnyville	1980-12-11-01	SE14-61-05-4	Charlotte L.	NIL	0	0	0	drainage of sewage lagoon
					TOTAL 3472.2	30.8	621.7	641.5	
GROUND WATER									
	no licences								

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[a] double entry - also in Reach 210; water is withdrawn in Reach 210, returned in Reach 224

[b] start-up 1981

REACH NO. 233					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
SURFACE WATER									
	MUNICIPAL								
9029	Canada National Defense	1951-01-15-02	NW24-63-02-4	Cold Lake	1153.3	1099.3	922.6	879.4	base supply
18450[a]	Town of Grande Centre	1978-01-16-01	NW04-63-02-4	Cold Lake	2115.4	568.6	-	-	urban supply
19473[b]	Town of Cold Lake	1979-09-06-02	SW25-63-02-4	Cold Lake	8634.4[r]	287.7	-	-	urban supply
	DIVERSION								
12630	Town of Cold Lake	1960-11-29-01	SW24-63-02-4	Medley R.	NIL	0	0	0	flood control
				TOTAL	11903.1	1955.6	922.6	879.4	
GROUND WATER									
	no licences								

[a] double entry; withdrawal is from Reach 233; returns are to Reach 530.

[b] double entry; withdrawal is from Reach 233; returns are to Reach 521.

[r] requested

REACH NO. 503

FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	WITHDRAWALS (dam^3/yr) AUTHORIZED OR LICENCED	WITHDRAWALS (dam^3/yr) 1980	RETURNS (dam^3/yr) ULTIMATE	RETURNS (dam^3/yr) 1980	COMMENTS
SURFACE WATER									
	DOMESTIC								
10216	Vallee, Maurice	1960-02-19-03	SW16-02-10-4	coulee 97	6.2	6.2	0	0	stockwatering reservoir
12781	Evans, Francis	1969-07-09-04	SW09-64-11-4	coulee 15	3.7	3.7	0	0	stockwatering reservoir
12958	Ratcliffe, George	1969-11-28-04	NE07-64-13-4	coulee 16	2.5	2.5	0	0	stockwatering reservoir
14660	Romanyshyn, Don	1981-03-25-01	SE22-66-17-4	coulee	1.2	1.2	0	0	stockwatering reservoir
	MUNICIPAL								
12367	Village of Boyle	1968-03-29-01	NW12-65-19-4	Skeleton L.	111.0	107.3	0	0[a]	urban supply
17473	Co.St.Paul-Mallaig	1975-12-18-01	SE28-60-10-4	Denning L.	13.6	19.7	10.9	15.8	urban supply
	IRRIGATION								
12617	Meyer, Glen	1969-02-10-02	SE13-65-17-4	slough 14	67.8	67.8	0	0	56 acres
13945	Caslan Metis Colony	1972-04-06-02	NW34-64-17-4	slough	37.0	37.0	0	0	30 acres
	INDUSTRIAL								
796	Alta & Great Waterwy Railway	1915-09-10-02	SE13-66-15-4	Missawawi L.	90.0	0	0	0	stream trains
	OTHER								
3732	Independent Fish-pool	1937-07-29-02	NE13-66-14-4	Beaver R.	12.3	0	0	0	fish ponds
6966	Dept. Indian Affairs	1944-05-10-02	0003-66-13-4	Cross L.	0[b]	0	0	0	fur conservation
7565	Adams, Cyril	1947-03-06-01	SW29-64-17-4	Amisk River	NIL	0	0	0	fur farming
14071	Ducks Unlimited	1953-04-30-01	NE27-62-13-4	Whitefish Cr.	8702.2	0	0	0	wildfowl propagation
14084	Ducks Unlimited	1953-04-30-01	NE27-61-12-4	Creek 95	1233.5	0	0	0	wildfowl propagation
14086	Ducks Unlimited	1953-07-21-02	NE08-61-11-4	Creek 96	1233.5	0	0	0	wildfowl propagation

REACH NO. 503 (Continued)

FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	WITHDRAWALS (dam^3/yr) AUTHORIZED OR LICENCED	WITHDRAWALS (dam^3/yr) 1980	RETURNS (dam^3/yr) ULTIMATE	RETURNS (dam^3/yr) 1980	COMMENTS
	STORAGE								
19933	Ducks Unlimited	1974-01-18-01	1314-63-11-4	Fork Lake	NIL	0	0	0	lake stabilization
	DIVERSION								
892	MacPherson, D.	1918-05-16-01	SW05-061-10-4	Creek	NIL	0	0	0	flood control
1595	McDonald, G. & McPherson	1920-08-17-01	SW05-061-10-4	Creek	0^r	0	0	0	flood control
1681	Richard, D. & Cusson, B.	1922-06-14-01	NW26-065-12-4	Beaver L.	0^r	0	0	0	flood control
1690	Sowler, R. & Smith, C.B.	1923-02-03-01	NW29-061-11-4	Coulee	NIL	0	0	0	flood control
					TOTAL 11514.5	245.4	10.9	15.8	
GROUND WATER									
	no licences								

[a] all water is removed from the Beaver River Basin
[b] no amount stated; assume zero
[r] requested

REACH NO. 509					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
	SURFACE WATER								
	no licences								
	GROUND WATER								
	INDUSTRIAL								
19260	Amoco Canada Petro.	1980-09-09-01	0604-63-08-4	aquifer	143.1^{r}	0	0	0	injection
14542	Canada Cities Service	1981-04-08-01	0613-63-08-4	aquifer	29.6^{r}	0	0	0	injection
				TOTAL	172.7	0	0	0	

^{r} requested

REACH NO. 510					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
	SURFACE WATER								
	OTHER								
8735-B	Town of Bonnyville	1950-10-10-06	NE34-61-07-4	Yelling Cr.	NIL^r	0	0	0	Wildfowl propogation
				TOTAL	NIL	0	0	0	
	GROUND WATER								
	no licences								

^{r} requested

REACH NO. 511					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
	SURFACE WATER								
	DIVERSION								
17066	M.D. Bonnyville	1975-03-20-10	SW11-61-09-4	slough	NIL	0	0	0	drainage
				TOTAL	NIL	0	0	0	
	GROUND WATER								
	no licences								

REACH NO. 516					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
SURFACE WATER									
	DIVERSION								
847-A	Scott, W.S.	1916-10-11-01	0016-63-05-4	Jackfish Cr.	NIL[r]	0	0	0	flood control
847-A	M.D. Bonnyville	1966-07-29-06	SW22-63-05-4	Jackfish Cr.	NIL	0	0	0	Jackfish Cr. flood control
847-B	M.D. Bonnyville	1966-07-29-07	NE06-63-05-4	Jackfish Cr.	NIL	0	0	0	LaCorey flood control
847	M.D. Bonnyville	1978-08-11-02	SW05-63-05-4	slough	NIL	0	0	0	LaCorey flood control
17375	M.D. Bonnyville	1975-10-20-02	SW29-63-05-4	coulee	NIL	0	0	0	LaCorey North drainage
				TOTAL	NIL	0	0	0	
GROUND WATER									
	no licences								

[r] requested

REACH NO. 517

FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		COMMENTS
					AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	
SURFACE WATER									
	DIVERSION								
19664	M.D. Bonnyville	1968-08-28-04	SW26-62-05-4	Beaver R.	NIL	0	0	0	flood control
16998	M.D. Bonnyville	1975-05-15-04	SW19-62-05-4	coulee	NIL	0	0	0	drainage
				TOTAL	NIL	0	0	0	
GROUND WATER									
	INDUSTRIAL								
15286	Belvedere Developments	1981-08-04-01	SW19-62-05-4	aquifer	165.3	0	0	0	subdivision supply

REACH NO. 521

FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	WITHDRAWALS (dam^3/yr) AUTHORIZED OR LICENCED	WITHDRAWALS (dam^3/yr) 1980	RETURNS (dam^3/yr) ULTIMATE	RETURNS (dam^3/yr) 1980	COMMENTS
SURFACE WATER									
	MUNICIPAL								
19473[a]	Town of Cold Lake	1979-09-06-02	SW25-63-02-4	Cold Lake	-	-	6907.5	230.2	urban supply
	STORAGE								
13404	M.D. Bonnyville	1975-09-15-01	SE13-63-03-4	Maloney L.	NIL	0	0	0	lake stabilization
	DIVERSION								
1639	M.D. Bonnyville	1958-10-21-01	SW03-63-02-4	Fontaine L.	NIL	0	0	0	flood control
16487[b]	Town of Grand Centre	1976-05-18-01	SE03-63-02-4	aquifer	-	-	1204.0	1204.0	6 wells aquifer dewatering
19082	Madison Develop. Corp.	1979-01-22-02	NW13-63-02-4	surface run-off	NIL	0	0	0	flow control
19314	Canada National Defense	1979-08-30-01	SE12-63-03-4	Marie Cr.	NIL	0	0	0	channel alignment
1639	Town of Grand Centre	1979-09-05-03	NE33-62-02-4	surface run-off	NIL	0	0	0	drainage
				TOTAL	NIL	0	8111.5	1434.2	
GROUND WATER									
	DIVERSION								
16487[b]	Town of Grand Centre	1976-05-18-01	SE03-63-02-4	aquifer	215.9[b]	215.9	0	0	aquifer dewatering
16487[b]	Town of Grand Centre	1976-05-08-02	SW02-63-02-4	aquifer	218.1	218.1	0	0	aquifer dewatering
16487[b]	Town of Grand Centre	1976-05-08-03	SW02-63-02-4	aquifer	240.8	240.8	0	0	aquifer dewatering
16487[b]	Town of Grand Centre	1976-05-08-04	SW02-63-02-4	aquifer	240.8	240.8	0	0	aquifer dewatering
16487[b]	Town of Grand Centre	1976-05-08-05	SE03-63-02-4	aquifer	95.4	95.4	0	0	aquifer dewatering
16487[b]	Town of Grand Centre	1976-05-08-06	SE03-63-02-4	aquifer	168.1	168.1	0	0	aquifer dewatering
				TOTAL	1204.0	1204.0	0	0	

[a] double entry; withdrawal from Reach 233; returns to Reach 521.

[b] double entry; groundwater is pumped from the aquifer and discharged on the surface; licence is only temporary and should be discontinued in 1981.

REACH NO. 525

FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	WITHDRAWALS (dam^3/yr) AUTHORIZED OR LICENCED	WITHDRAWALS (dam^3/yr) 1980	RETURNS (dam^3/yr) ULTIMATE	RETURNS (dam^3/yr) 1980	COMMENTS
	SURFACE WATER								
	MUNICIPAL								
17888[a]	M.D. Bonnyville (Ardmore - Ft.Kent)	1979-04-25-01	0832-61-04-4	aquifer	-	-	40.4	37.8	urban return flows
	DIVERSION								
12463	M.D. Bonnyville	1967-11-20-03	NE09-62-03-4	Muriel Cr.	NIL	0	0	0	East Ardmore - flood control
				TOTAL	0	0	40.4	37.8	
	GROUND WATER								
	MUNICIPAL								
17888[a]	M.D. Bonnyville (Ardmore - Ft. Kent)	1979-04-25-01	0832-61-04-4	aquifer	50.6[b]	47.2	0	0	urban supply
	INDUSTRIAL								
16943	Suncor Inc. Resource Gr.	1978-03-08-02	0328-61-04-4	aquifer	333.0	198.6[c]	0	0	injection
16943	Suncor Inc. Resource Gr.	1980-08-08-01	0228-61-04-4	aquifer	NIL	3.7[c]	0	0	injection - standby
19310	Tru-Mix Concrete	1981-03-03-01	0224-61-05-4	aquifer	1.2	0[d]	0	0	processing
				TOTAL	384.8	249.5	0	0	

[a] double entry; sewage flows are disposed of on the surface.
[b] increase requested to 67.8 x 1000m^3/yr.
[c] 1979 figures
[d] start-up in 1981

REACH NO. 526					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
SURFACE WATER									
	no licences								
GROUND WATER									
	INDUSTRIAL								
15725[a]	Union Texas of Canada	1975-02-04-02 1980-02-29-01	1320-63-03-4	aquifer	59.2 88.8	36.2[b]	0	0	injection
15725[a]	Union Texas of Canada	1975-02-04-03 1980-02-29-02	1420-62-03-4	aquifer	59.2 88.8	30.8[b]	0	0	injection
				TOTAL	296.0	67.0			

[a] two wells under one file number; each well has two unique numbers since the authorized withdrawal was increased in 1980.

[b] 1979 figures.

REACH NO. 529

FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	WITHDRAWALS (dam^3/yr) AUTHORIZED OR LICENCED	WITHDRAWALS (dam^3/yr) 1980	RETURNS (dam^3/yr) ULTIMATE	RETURNS (dam^3/yr) 1980	COMMENTS
SURFACE WATER									
	DIVERSION								
12716	Alberta Municipal Affairs	1963-09-03-01	NE35-59-03-4	coulee	0^r	0	0	0	Reita L. flood control
12716	Alberta Municipal Affairs	1963-09-03-02	SE01-61-03-4	coulee	0^r	0	0	0	Reita L. flood control
				TOTAL	0	0	0	0	
GROUND WATER									
	no licences								

^{r} requested

REACH NO. 530					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
	SURFACE WATER								
	MUNICIPAL								
18450[a]	Town of Grand Centre	1978-01-16-01	NW04-63-02-4	Cold Lake	-	-	1692.3	454.9	urban supply

[a] double entry; withdrawal is from Reach 233; returns to Reach 530.

REACH NO. 540					WITHDRAWALS (dam^3/yr)		RETURNS (dam^3/yr)		
FILE NO.	PURPOSE-USER	UNIQUE NO.	LOCATION	SOURCE	AUTHORIZED OR LICENCED	1980	ULTIMATE	1980	COMMENTS
	SURFACE WATER								
	IRRIGATION								
12381	Babey, W.	1968-05-03-11	SW32-60-02-4	slough 12	43.2	43.2	0	0	77 acres
	INDUSTRIAL								
17667	Chevron Standard Ltd.	1976-05-07-02	SE36-61-02-4	Beaver R.	172.7	0[a]	0	0	injection
				TOTAL	215.9	43.2	0	0	
	GROUND WATER								
	no licences								

[a] start-up in 1981

APPENDIX C

WATER QUALITY CRITERIA

APPENDIX C-1

DRINKING WATER QUALITY STANDARDS

SUMMARY OF RECOMMENDED LIMITS

Parameter	Maximum Acceptable Concentration*	Objective Concentration*	Basis**
Aldrin + Dieldrin	0.0007	$\leq 5 \times 10^{-8}$	H
Antimony	—	≤ 0.0002	H
Arsenic	0.05	≤ 0.005	H
Asbestos	—	—	—
Barium	1.0	≤ 0.1	H
Boron	5.0	≤ 0.01	H
Cadmium	0.005	≤ 0.001	H
Carbaryl	0.07	$\leq 5 \times 10^{-4}$	H
Chlordane (Total)	0.007	$\leq 5 \times 10^{-8}$	H
Chloride	250	<250	A
Chromium	0.05	≤ 0.0002	H
Colour (TCU)	15	<15	A
Copper	1.0	<1.0	A
Cyanide	0.2	≤ 0.002	H
DDT (Total)	0.03	$\leq 5 \times 10^{-8}$	H
Diazinon	0.014	$\leq 1 \times 10^{-6}$	H
Dieldrin + Aldrin	0.0007	$\leq 5 \times 10^{-8}$	H
Endrin	0.0002	$\leq 5 \times 10^{-8}$	H
Fluoride	1.5	1.0***	H & A
Hardness	—	—	—
Heptachlor + Heptachlor Epoxide	0.003	$\leq 5 \times 10^{-8}$	H
Iron	0.3	<0.05	A
Lead	0.05	≤ 0.001	H
Lindane	0.004	$\leq 1 \times 10^{-7}$	H
Manganese	0.05	<0.01	A
Mercury	0.001	≤ 0.0002	H
Methoxychlor	0.1	$\leq 5 \times 10^{-8}$	H
Methyl Parathion	0.007	$\leq 1 \times 10^{-6}$	H
Nitrate (as N)	10.0	≤ 0.001	H
Nitrilotriacetic Acid (NTA)	0.05	≤ 0.0002	H
Nitrite (as N)	1.0	≤ 0.001	H
Odour	—	Inoffensive	A
Parathion	0.035	$\leq 1 \times 10^{-6}$	H
Pesticides (Total)****	0.1	—	H
pH	6.5 – 8.5	—	A
Phenols	0.002	<0.002	A
Selenium	0.01	≤ 0.002	H
Silver	0.05	≤ 0.005	H
Sodium	—	—	—
Sulphate	500	<150	H & A
Sulphide (as H_2S)	0.05	<0.05	A
Taste	—	Inoffensive	A

Parameter	Maximum Acceptable Concentration*	Objective Concentration*	Basis**
Temperature (°C)	15	<15	A
Total Dissolved Solids	500	—	A
Total Organic Carbon	—	—	—
Toxaphene	0.005	$\leq 5 \times 10^{-6}$	A
Trihalomethanes	0.35	≤0.0005	H
Turbidity (NTU)	5	<1	H & A
Uranium	0.02	≤0.001	H
Zinc	5.0	<5.0	A
2, 4-D	0.1	≤0.001	H
2, 4, 5-TP	0.01	≤0.001	H

* Unless indicated otherwise, the maximum acceptable and objective concentrations are specified in mg/L.

** Maximum acceptable and objective concentrations have been established on the basis of either aesthetic (A) or health (H) considerations.

*** In areas where the annual mean maximum temperature is below 10°C, the objective is 1.2 mg/L.

**** The "total pesticides" limit applies to water in which more than one of the pesticides listed in this Table is present, in which case, the sum of their concentrations should not exceed 0.1 mg/L.

RECOMMENDED LIMITS FOR RADIONUCLIDES IN DRINKING WATER

Radionuclides	Maximum Acceptable Concentration Bq/L	Target Concentration Bq/L
Cesium-137	50	5
Iodine-131	10	1
Radium-226	1	0.1
Strontium-90	10	1
Tritium	40 000	4 000

MAXIMUM ACCEPTABLE LEVEL FOR COLIFORMS

1) *no sample should contain more than 10 total coliform organisms per 100 mL; and*
2) *not more than 10 percent of the samples taken in a 30-day period should show the presence of coliform organisms; and*
3) *not more than 2 consecutive samples from the same site should show the presence of coliform organisms; and*
4) *none of the coliform organisms detected should be fecal coliforms.*

Source: Health and Welfare Canada, 1979. pp. 74,61, 26.

Appendix C-2

EXAMPLE OF BOILER MAKE-UP WATER QUALITY CRITERIA

PARAMETER [(a)]	(b) Low Pressure (0-150 psig)	(b) Intermediate Pressure (150-700 psig)	(b) High Pressure (700-1500 psig)	2000 psig Once Through 80% Steam	2000 psig Utility Type 3% Blowdown	2000 psig Saline Type 80% Steam
Silica (SiO_2)	30	10	0.7	10	.01	10
Aluminum	5	0.1	0.01	-	-	-
Iron (Fe)	1	0.3	0.05	0.05	0.01	0.05
Manganese (Mg)	0.3	0.1	0.01	-	-	-
Ammonia (NH_4)	0.1	0.1	0.1	-	-	-
Bicarbonate (HCO_3)	170	120	48	-	-	-
Sulfate (SO_4)	(c)	(c)	(c)	-	-	-
Choloride (Cl)	(c)	(c)	(c)	-	-	-
Dissolved Solids	700	500	200	400	0.05	no limit
Copper (Cu)	0.5	0.05	0.05	-	-	-
Zinc (Zn)	(c)	(d)	(d)	-	-	-
Hardness ($CaCO_3$)	20	(d)	(d)	1	0	1
Free Mineral Acidity ($CaCO_3$)	(d)	(d)	(d)	-	-	-
Alkalinity ($CaCO_3$)	140	100	40	-	-	-
pH Units	8.0 - 10.0	8.2 - 10.0	8.2 - 9.0	8.5	9.5	8.5
Colour Units	(c)	(c)	(c)	-	-	-
Organics						
- Methylene Blue Active Substances	1	1	0.5	-	-	-
- Carbon Tetracholoride Extract	1	1	0.5	-	-	-
- Chemical Oxygen Demand (O_2)	5	5	0.5	-	-	-
- Dissolved Oxygen (O_2)	2.5	0.007	0.007	0.007	0.001	0.007
- Temperature (°F)	(c)	(c)	(c)	-	-	-
- Suspended Solids	10	5	(d)	nil	nil	nil
- Sulfides	-	-	-	nil	nil	nil
- Oil	-	-	-	nil	nil	nil

(a) All values in mg/l unless noted. Values should not be exceeded.
(b) Quality prior to internal conditioning.
(c) Accepted as received.
(d) Zero.

from: Stanley Associates Engineering Ltd., 1978, p. 2.7.

Appendix C-3

EXAMPLE OF COOLING WATER - RECIRCULATING SYSTEMS WATER QUALITY CRITERIA (1)

Parameter	Concentration
Silica (SiO_2)	5.0
Aluminum (Al) 1	0.1
Iron (Fe)	0.5
Manganese (Mn)	0.5
Calcium (Ca)	50
Magnesium (Mg)	(2)
Ammonia (NH_4)	(2)
Bicarbonate (HCO_3)	24
Sulfate (SO_4)	200
Chloride (Cl)	500
Dissolved Solids	500
Copper (Cu)	(2)
Zinc (Zn)	(2)
Hardness ($CaCO_3$)	130
Free Mineral Acidity ($CaCO_3$)	(2)
Alkalinity ($CaCO_3$)	20
pH (Units)	(2)
Colour (Units)	(2)
Organics	
Methylene Blue Active Substance	1
Carbon Tetrachloride Extract	1
Chemical Oxygen Demand	75
Dissolved Oxygen (O_2)	(2)
Temperature (^{o}F)	(2)
Suspended Solids	100

(1) Units in mg/l unless otherwise indicated.

(2) Accepted as received (if meeting total solids or other limited values); has never been a problem at the concentrations encountered.

from: Stanley Associates Engineering Ltd., 1978, p. 2.11.

APPENDIX C-4

EXAMPLE OF PETROLEUM INDUSTRY PROCESS/UTILITY WATER REQUIREMENTS AT POINT OF USE (1)

Parameter	Concentration Before Use
Silica (SiO_2)	50
Iron (Fe)	15
Calcium (Ca)	220
Magnesium (Mg)	85
Total Sodium & Potassium (Na) (K)	230
Bicarbonate (HCO_3)	480
Sulfate (SO_4)	570
Chloride (Cl)	1600
Fluoride (F)	1.2
Nitrate (NO_3)	8
Dissolved Solids	3500
Suspended Solids	5000
Hardness as ($CaCO_3$)	900
Noncarbonate Hardness as ($CaCO_3$)	
Colour (Units)	25
pH (Units)	

(1) all concentrations in mg/l except where noted

NOTE: These criteria refer to quality of water prior to the addition of substances used for internal conditioning.

from: Stanley Associates Engineering Ltd., 1978, p. 2.12.

APPENDIX C-5

SEWAGE EFFLUENT QUALITY CRITERIA

CRITERIA FOR SECONDARY TREATMENT
(including aerated lagoons)

Parameter	% Removal	Effluent Value
1. Ammonia Nitrogen	—	10-20 mg/l
2. BOD (5-day @ 20 degrees C)	85-95	15-30mg/1
3. Coliform Bacteria	99.5-99.9	20,000-200,000 per 100 ml
4. MBAS	80-95	0.2-0.8 mg/l
5. Dissolved Oxygen	—	3-5 mg/l
6. Oil and Grease (Ether Solubles)*	—	15-25 mg/l
7. pH	—	5.5-10.5
8. Phenolics*	—	20-40 ppb
9. Suspended Solids	85-95	15-30 mg/l
10. Phosphorus as PO_4	—	15-30 mg/l
11. Temperature	—Not to be increased by more than 3 degrees C above ambient water temperature.	
12. Odour	—The cold (20 degrees C) threshold odour number not to exceed eight.	
13. Colour	—Transmittance not to be decreased more than 30% below natural value.	
14. Turbidity	—Not to exceed more than 25 Jackson units over natural turbidity.	

*Applied to any effluent regardless of treatment.

CRITERIA FOR CONVENTIONAL AEROBIC LAGOONS

Parameter	%Removal		Effluent Value (Summer)
	Winter	Summer	
1. BOD (5-day @ 20 degrees C)	25-65	85-95	15-30 mg/l
2. Coliform Bacteria	90	99.5	20,000-200,000 per 100 ml
3. MBAS	—	60-90	0.2-1.5 mg/l
4. Suspended Solids	75-90	70-95	15-100 mg/l*
5. Algae	—	—	150-300 ppm (vol.)
6. Phosphorus as PO_4			5-20 mg/l

*Includes algae

NOTE. 1. The effluent value figures may not apply to industrial wastes since industrial pollution loading may be based on units of production or total daily output of pollution substances.

2. In using these criteria, it should be kept in mind that they are all interrelated and that it would be unwise to be guided solely by the contents of one table without reference to the others.

"In determining the final treatment criteria for sewage effluent, the method and location of disposal is considered. Before a continuous discharge to a watercourse is permitted, the minimum average monthly flow in the stream must be a minimum of ten times the average daily flow of sewage effluent discharged to that stream. If the proposed receiving stream does not meet these flow requirements, storage of the effluent will be required with periodic discharge as authorized and approved by the Director of Standards and Approvals Division of Alberta Environment."
Source: Alberta Environment, 1978, p. 36.

Appendix C- 6

ESTIMATED EFFLUENT QUALITY FOR MEDIUM-SIZED HEAVY OIL EXTRACTION PLANTS *

Parameter	Concentration (mg/l)
Calcium	180
Magnesium	120
Sodium	1000
Chloride	1000
Silica	16
Sulphate	150
Biological Oxygen Demand	10
Suspended Solids	25

* Ion exchange backwash and sewage only.

Source: Alberta Environment, Johnston, 1981.

Appendix C-7

DEPOSITS TO BEAVER RIVER - ESSO PROPOSED COMMERCIAL HEAVY OIL PLANT (kg/day)

PARAMETER	EFFLUENT 4.2 x $10^3 m^3$/d		MAX. ALLOWABLE FOR RIVER FLOWS IN m^3/s of				AVERAGING PERIOD
	mg/l	Kg/D	0.4 - 1.2	1.2 - 3.7	3.7 - 15.0	>15.0	
Chemical Oxygen Demand	28	118	550	(Same as for Minimum Flow)			Month
Chromium (+6)	0.01	.05	2	"			"
Phosphorous (As PO_4)	0.25	1.1	5	"			"
Zinc	0.02	0.1	1.3	"			"
Total Suspended Solids	18.3	77	220	"			"
Oil and Grease	1.3	5.5	22	"			"
Sulphides	0.05	.21	0.8	"			"
Ammonia - Nitrogen	3.05	12.8	22	"			"
Threshold Odour No.		(48)	(60)	"			"
Sulphate	2860	12000*	500	4400	13000	26000	Week
Sodium	1545	6492*	350	3300	9800	19600	"
Chlorides	637	2677*	550	5400	7900	7900	"
Phenols	0.014	.06*	.02	.20	.70	1.3	"
Total Copper	0.002	.01	.02	.20	.70	1.3	"
Total Dissolved Solids	6246	26234	1900	17300	50000	97000	"
Probable Duration (weeks/years)			1	8	23	20	"

* Effluent will be impounded in cooling pond as needed to meet maximum allowable deposits at river flows below 3.7 m^3/s.

from: Esso Resources Canada Ltd., 1981, letter.

Appendix C- 8

SURFACE WATER QUALITY OBJECTIVES

These objectives represent water quality suitable for most uses either through direct use or prepared for use by an economically practical degree of treatment. They apply to surface waters except in areas of close proximity to outfalls.

There are many instances where the natural water quality of a lake or river does not meet some of the suggested limits. In these cases, the limits obviously will not apply. It should be noted, however, that where the natural existing quality is inferior to desirable criteria, it would be unwise to permit further deterioration by unlimited or uncontrolled introduction of pollutants. Naturally occurring circumstances are not taken into account in these objectives and due consideration must be given where applicable (e.g. spring runoff effect on colour, odour, etc.).

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1. Bacteriology (Coliform Group)

(a) In waters to be withdrawn for treatment and distribution as a potable supply or used for outdoor recreation other than direct contact, at least 90 per cent of the samples (not less than five samples in any consecutive 30-day period) should have a total coliform density of less than 5,000 per 100 ml and a fecal coliform density of less than 1,000 per 100 ml.

(b) In water used for direct contact recreation or vegetable crop irrigation the geometric mean of not less than five samples taken over not more than a 30-day period should not exceed 1,000 per 100 ml total coliforms, nor 200 per 100 ml fecal coliforms, nor exceed these numbers in more than 20 per cent of the samples examined during any month, nor exceed 2,400 per 100 ml total coliforms on any day.

2. Dissolved Oxygen

A minimum of five mg/l at any time.

3. Biochemical Oxygen Demand

Dependent on the assimilative capacity of the receiving water, the BOD must not exceed a limit which would create a dissolved oxygen content of less than five mg/l.

4. Suspended Solids

Not to be increased by more than 10 mg/l over background value.

5. pH

To be in the range of 6.5 to 8.5 pH units but not altered by more than 0.5 pH units from background value.

6. Temperature

Not to be increased by more than 3°C above ambient water temperature.

7. Odour

The cold (20°C) threshold odour number not to exceed eight.

8. Colour

Not to be increased more than 30 colour units above natural value.

9. Turbidity

Not to exceed more than 25 Jackson units over natural turbidity.

10. Organic Chemicals

Constituent	Maximum Concentration (mg/l)
Carbon Chloroform Extract (CCE) (includes Carbon Alcohol Extract)	0.2
Methyl Mercaptan	0.05
Methylene Blue Active Substances	0.5
Oil and Grease	substantially absent, no irridescent sheen
Phenolics	0.005
Resin Acids	0.1

11. Pesticides

To provide reasonably safe concentrations of these materials in receiving waters an application shall not exceed 1/100 of the 48-hour TL_m. No pesticides can be used in Alberta unless they have been registered under the Pest Control Products Act. Any pesticides used on, in, or near water (within 100 linear feet) must be approved by a Department of Environment permit issued under The Agricultural Chemicals Act.

12. Toxic Chemicals

Constituent	Maximum Concentration (mg/l)
Arsenic	0.01
Barium	1.0
Cadmium	0.01
Chromium	0.05
Cyanide	0.01
Lead	0.05
Mercury	0.0001
Selenium	0.01
Silver	0.05

13. Radioactivity

Gross Beta not to exceed 1,000 pCi/l.
Radium 226 not to exceed three pCi/l.
Strontium 90 not to exceed 10 pCi/l.

14. Inorganic Chemicals

Constituent	Maximum Concentration (mg/l)
Boron	0.5
Copper	0.02
Fluoride	1.5
Iron	0.3
Manganese	0.05
Nitrogen (Total Inorganic and Organic)	1.0
Phosphorus as PO_4 (Total Inorganic and Organic) ...	0.15
Sodium (as percent of cations)	between 30 & 75
Sulphide	0.05
Zinc	0.05

NOTE: The predominant cations of SODIUM, CALCIUM and MAGNESIUM and anions of SULPHATE, CHLORIDE and BICARBONATE are too variable in the natural water quality state to attempt to define limits. Nevertheless, in order to prevent impairment of water quality, where effluents containing these ions are discharged to a water body the permissible concentration will be determined by the administrative authority in accordance with existing quality and use.

15. Unspecified Substances

Substances not specified herein should not exceed values which are considered to be deleterious for the most critical use as established by the administrative authority.

Source: Alberta Environment, 1977, p. 5.

Appendix C- 9

PRAIRIE PROVINCES WATER BOARD INTERIM QUALITY REQUIREMENTS AT PPWB BEAVER RIVER STATION

Parameter	Requirement (mg/l)
Alkalinity (HCO_3)	360
Calcium	80
Chloride	30
Magnesium	40
Potassium	10
Sodium	40
Sulphate	50
Total Dissolved Solids	525
pH (in pH units)	6.5-9.0
Silica (Reactive)	30
Chromium (Total)	0.05
Copper (Total)	0.003
Phenolics	0.005
Dissolved Oxygen	
April to December	$\geq$ 6.0 or 50% saturation
December to March	3.0
Total Phosphorus	0.22
Total Nitrogen	2.6
Sulphides	0.002
Dissolved Iron	0.3
Suspended Solids	40
Temperature	$\Delta T < 3^{\circ}C$ from ambient

Source: Prairie Provinces Water Board, 1979, p. 14.

APPENDIX D

FUTURE DOMESTIC AND MUNICIPAL WATER WITHDRAWALS AND RETURNS

DOMESTIC AND MUNICIPAL WATER WITHDRAWALS - 1985

	Water Source	Reach Number	per capita demand ℓ/day	Surface Water (dam^3/yr) low	Surface Water (dam^3/yr) high	Groundwater (dam^3/yr) low	Groundwater (dam^3/yr) high
Domestic (Rural)	groundwater	various	350	-	-	1290	1320
Municipal							
Ardmore-Ft. Kent	groundwater	525	350			60	60
Bonnyville	Moose Lake	210	450	840	860	-	-
CFB Cold Lake	Cold Lake	233	680	1360	1360	-	-
Cold Lake-Grand Centre	Cold Lake	233	450	1160	1290	-	-
Glendon	groundwater	511	350	-	-	70	80
Indian Reserves							
Beaver Lake	groundwater	503	200	-	-	20	20
Cold Lake	Cold Lake	233	200	90	90	-	-
Kehewin Lake	Kehewin Lake	210	200	60	60	-	-
Whitefish Lake	Whitefish Lake	503	200	50	50	-	-
Mallaig	Denning Lake	503	350	30	30	-	-
Other (Boyle)	Skeleton Lake	503	350	100	100	-	-
TOTAL				3690	3840	1440	1480

DOMESTIC AND MUNICIPAL WATER RETURNS - 1985

	Return Location	Reach Number	Surface Water (dam^3/yr) Low	Surface Water (dam^3/yr) High	On-Site (dam^3/yr) Low	On-Site (dam^3/yr) High
Domestic (Rural)	on-site	various	-	-	1032	1056
Municipal						
Ardmore-Ft. Kent	Muriel Creek	525	48	48	-	-
Bonnyville	Muriel Creek	224	672	688	-	-
CFB Cold Lake	Marie Creek	521	1088	1088	-	-
Cold Lake-Grand Centre	Beaver River	530	928	1032	-	-
Glendon	Columbine Creek	511	56	64	-	-
Indian Reserves						
Beaver Lake	on-site	503	-	-	16	16
Cold Lake	on-site & Reita Creek	529	8	8	64	64
Kehewin Lake	on-site	210	-	-	48	48
Whitefish Lake	on-site & Goodfish Lake	503	0	0	40	40
Mallaig	on-site	503	-	-	24	24
Other (Boyle)	out of basin	-	-	-	-	-
TOTAL			2800	2928	1224	1248

DOMESTIC AND MUNICIPAL WATER WITHDRAWALS - 2000

	Water Source	Reach Number	per capita demand ℓ/day	Surface Water (dam^3/yr)		Groundwater (dam^3/yr)	
				low	high	low	high
Domestic (Rural)	groundwater	various	350	-	-	2230	2770
Municipal							
Ardmore-Ft. Kent	groundwater	525	350	-	-	100	180
Bonnyville	Moose Lake	210	450	1460	1920	-	-
CFB Cold Lake	Cold Lake	233	680	1610	1610	-	-
Cold Lake-Grand Centre	Cold Lake	233	450	1990	5210	-	-
Glendon	groundwater	511	350	-	-	120	200
Indian Reserves							
Beaver Lake	groundwater	503	200	-	-	40	40
Cold Lake	Cold Lake	233	200	150	150	-	-
Kehewin Lake	Kehewin Lake	210	200	100	100	-	-
Whitefish Lake	Whitefish Lake	503	200	80	80	-	-
Mallaig	Denning Lake	503	350	60	90	-	-
Other (Boyle)	Skeleton Lake	503	350	160	160	-	-
TOTAL				5610	9320	2490	3190

DOMESTIC AND MUNICIPAL WATER RETURNS - 2000

	Return Location	Reach Number	Surface Water (dam^3/yr)		On-Site (dam^3/yr)	
			Low	High	Low	High
Domestic (Rural)	on-site	various	-	-	1784	2216
Municipal						
Ardmore-Ft. Kent	Muriel Creek	525	80	144	-	-
Bonnyville	Muriel Creek	224	1168	1536	-	-
CFB Cold Lake	Marie Creek	521	1288	1288	-	-
Cold Lake-Grand Centre	Beaver River	530	1592	4168	-	-
Glendon	Columbine Creek	511	96	160	-	-
Indian Reserves						
Beaver Lake	on-site	503	-	-	32	32
Cold Lake	on-site & Reita Creek	529	24	24	96	96
Kehewin Lake	on-site	210	-	-	80	80
Whitefish Lake	on-site & Goodfish Lake	503	0	0	64	64
Mallaig	on-site	503	-	-	48	72
Other (Boyle)	out of basin	-	-	-		
TOTAL			4248	7320	2104	2560

DOMESTIC AND MUNICIPAL WATER WITHDRAWALS - 2015

	Water Source	Reach Number	per capita demand ℓ/day	Surface Water (dam^3/yr)		Groundwater (dam^3/yr)	
				low	high	low	high
Domestic (Rural)	groundwater	various	350	-	-	3790	4300
Municipal							
Ardmore-Ft. Kent	groundwater	525	350	-	-	170	240
Bonnyville	Moose Lake	210	450	2460	2990	-	-
CFB Cold Lake	Cold Lake	233	680	1860	1860	-	-
Cold Lake-Grand Centre	Cold Lake	233	450	3040	6140	-	-
Glendon	groundwater	511	350	-	-	210	270
Indian Reserves							
Beaver Lake	groundwater	503	200	-	-	60	60
Cold Lake	Cold Lake	233	200	250	250	-	-
Kehewin Lake	Kehewin Lake	210	200	180	180	-	-
Whitefish Lake	Whitefish Lake	503	200	140	140	-	-
Mallaig	Denning Lake	503	350	90	130	-	-
Other (Boyle)	Skeleton Lake	503	350	290	290	-	-
TOTAL				8310	11980	4230	4870

DOMESTIC AND MUNICIPAL WATER RETURNS - 2015

	Return Location	Reach Number	Surface Water (dam^3/yr)		On-Site (dam^3/yr)	
			Low	High	Low	High
Domestic (Rural)	on-site	various	-	-	3032	3440
Municipal						
Ardmore-Ft. Kent	Muriel Creek	525	136	240	-	-
Bonnyville	Muriel Creek	224	1968	2392	-	-
CFB Cold Lake	Marie Creek	521	1488	1488	-	-
Cold Lake-Grand Centre	Beaver River	530	2432	4912	-	-
Glendon	Columbine Creek	511	168	216	-	-
Indian Reserves						
Beaver Lake	on-site	503	-	-	48	48
Cold Lake	on-site & Reita Creek	529	40	40	160	160
Kehewin Lake	on-site	210	-	-	144	144
Whitefish Lake	on-site & Goodfish Lake	503	8	8	104	104
Mallaig	on-site	503	-	-	72	104
Other (Boyle)	out of basin	-	-	-	-	-
TOTAL			6240	9248	3560	4000

APPENDIX E

CURRENT AND FUTURE OIL COMPANY WATER WITHDRAWALS AND RETURNS

WATER USERS NAME: Amoco Canada Petroleum Co. Ltd.
REACH NUMBER: 509

PRESENT USE:

1980 WITHDRAWAL: 14 dam^3

SOURCE: Aquifer
LOCATION: Beaver River

SURFACE RETURN FLOW: 0

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR)	SOURCE	SURFACE RETURN (dam^3/YR.)	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)
1985	0	-	0	1160	Aquifer	0
2000	0	-	0	2320*	Aquifer	139
2015	0	-	0	0	-	0

COMMENTS:

* Assuming that 50% of total water requirement is met with recycled produce water.

Surface return water from backwash assumed to be equal to 3 % of total water requirements.

Produce water effluent to be deep injected in or below the formation.

WATER USERS NAME: BP Canada Inc.
REACH NUMBER: 206

PRESENT USE:

1980 WITHDRAWAL: 190 dam^3

SOURCE: Aquifer
LOCATION: Wolf River

SURFACE RETURN FLOW: 0

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR)	SOURCE	SURFACE RETURN (dam^3/YR.)	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)
1985	1100	Aquifer (if possible)	0	2190	Aquifer (if possible)	66
2000	2190	Aquifer (if possible)	66	2190*	Aquifer (if possible)	263
2015	2190	Aquifer (if possible)	66	2190*	Aquifer (if possible)	263

COMMENTS:

* Assuming that 75% of total water requirement is with recycled produce water.

Surface return water from backwash assumed to be equal to 3 % of total water requirements.

Produce water effluent to be deep injected in or below the formation.

WATER USERS NAME: Canada-Cities Service Ltd.
REACH NUMBER: 509

PRESENT USE:

1980 WITHDRAWAL: 30 dam^3

SOURCE: Aquifer
LOCATION: Sand River

SURFACE RETURN FLOW : 0

FUTURE USE :

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR)	SOURCE	SURFACE RETURN (dam^3/ YR.)	WITHDRAWAL (dam^3/ YR.)	SOURCE	SURFACE RETURN (dam^3/ YR.)
1985	0	-	0	410	Aquifer	0
2000	410	Aquifer	0	750*	Aquifer	45
2015	0	-	0	750*	Aquifer	45

COMMENTS:

* Assuming that 50% of total water requirement is met with recycled produce water.

Surface return from backwash assumed to be equal to 3 % of total water requirements.

Produce water effluent to be deep injected in or below the formation.

WATER USERS NAME: Chevron Standard Ltd.
REACH NUMBER: 540

PRESENT USE:

1980 WITHDRAWAL: 75 dam^3

SOURCE: Beaver River
LOCATION: Beaver River

SURFACE RETURN FLOW: 0

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR)	SOURCE	SURFACE RETURN (dam^3/YR.)	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)
1985	90	Beaver R.	0	550	Beaver R.	0
2000	0		0	1100*	Beaver R.	65
2015	0		0	1100*	Beaver R.	66

COMMENTS:

* Assuming that 50% of total water requirement is met with recycled produce water.

Surface return water from backwash assumed to be equal to 3 % of total water requirements.

Produce water effluent to be deep injected in or below the formation.

Aquitaine is participating in Chevron program.

WATER USERS NAME: Dome Petroleum Ltd.
REACH NUMBER: 216

PRESENT USE:

1980 WITHDRAWAL: 0
SOURCE:
LOCATION: Air weapons range

SURFACE RETURN FLOW:

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)
1985	690[1] 140[2]	Aquifer	0	830[3]	Aquifer	0
2000	0	-	0	7150*	Possibly Wolf Lake	0
2015	0	-	0	7150*	Possibly Wolf Lake	0

COMMENTS:

Process on one well involves two years of initial steaming followed by in-situ combustion for 7 years

1. Peak quantity needed during 2 years of steam phase (1 well).
2. quantity needed during normal air process operation on 1 well.
3. assumes steam phase has started on second well.

* Assuming that 50% of total water requirement is met with recycled produce water.

Produce water effluent to be deep injected in or below the formation.

WATER USERS NAME: Esso Resources Canada Ltd.
REACH NUMBER: 221

PRESENT USE:

1980 WITHDRAWAL: 130 dam^3

SOURCE: Ethel Lake
LOCATION: Ethel Lake

SURFACE RETURN FLOW: 0

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR)	SOURCE	SURFACE RETURN (dam^3/YR.)	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)
1985	2000	Ethel Lake	0	2000	Ethel Lake	0
2000	2000	Ethel Lake	0	2000	Ethel Lake	0
				21900	Possibly N. Sask. River	1500
2015	2000	Ethel Lake	0	2000	Ethel Lake	0
				21900	Possibly N. Sask. River	1500

COMMENTS:

Withdrawal and returns flows as supplied by Esso.

WATER USERS NAME: Gulf Canada Resources Inc.
REACH NUMBER: 233

PRESENT USE:

1980 WITHDRAWAL: 0

SOURCE:
LOCATION: Cold Lake

SURFACE RETURN FLOW: 0

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam ^{3}/YR)	SOURCE	SURFACE RETURN (dam ^{3}/YR.)	WITHDRAWAL (dam ^{3}/YR.)	SOURCE	SURFACE RETURN (dam ^{3}/YR.)
1985	0	-	-	350	Cold Lake	0
2000	0	-	-	1020*	Cold Lake	61
2015	0	-	-	1020*	Cold Lake	61

COMMENTS:

Current licence cancellation requested.

* Assuming that 50% of total water requirement is met with recycled produce water.

Surface return water from backwash assumed to be equal to 3 % of total water requirements.

Produce water effluent to be deep injected in or below the formation.

WATER USERS NAME: Husky Oil (Alberta) Ltd.
REACH NUMBER: 216

PRESENT USE:

1980 WITHDRAWAL: 0

SOURCE:
LOCATION: Tucker Lake

SURFACE RETURN FLOW:

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam³/YR.)	SOURCE	SURFACE RETURN (dam³/YR.)	WITHDRAWAL (dam³/YR.)	SOURCE	SURFACE RETURN (dam³/YR.)
1985	0	-	-	165	Probably Groundwater	0
2000	0	-	-	1220*	Unknown (Surface water?)	73
2015	0	-	-	1220*	Unknown (Surface water?)	73

COMMENTS:

* Assuming that 50% of total water requirement is met with recycled produce water.

Surface return water from backwash assumed to be equal to 3 % of total water requirements.

Produce water effluent to be deep injected in or below the formation.

WATER USERS NAME: Mobil Oil Canada Ltd.
REACH NUMBER: 212

PRESENT USE:

1980 WITHDRAWAL: 0

SOURCE: -
LOCATION: Barbara Lake

SURFACE RETURN FLOW:

FUTURE USE :

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR)	SOURCE	SURFACE RETURN (dam^3/YR.)	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)
1985	2	Surface Water	0	290	Surface Water	0
2000	580	Surface Water	0	2180*	Surface Water	131
2015	0	-	-	2180*	Surface Water	131

COMMENTS:

* Assuming that 50% of total water requirement is met with recycled produce water.

Surface return water from backwash assumed to be equal to 3 % of total water requirements.

Produce water effluent to be deep injected in or below the formation.

WATER USERS NAME: Murphy Oil Co. Ltd.
REACH NUMBER: 223

PRESENT USE:

1980 WITHDRAWAL: 46 dam^3

SOURCE: Tributary to Bluet Lake
LOCATION: Bluet Lake

SURFACE RETURN FLOWS: 0

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR)	SOURCE	SURFACE RETURN (dam^3/YR.)	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)
1985	310	Surface water	0	530	Surface water	0
2000	740*	Surface water	44	1500*	Surface water	90
2015	2200*	Surface water	132	4500*	Surface water	270

COMMENTS:

* Assuming that 50% of the total water requirement is met with recycled produce water.

Surface return water from backwash assumed to be equal to 3 % of total water requirements.

Produce water effluent to be deep injected in or below the formation.

WATER USERS NAME: Norcen Energy Resources Ltd.
REACH NUMBER: 132

PRESENT USE:

1980 WITHDRAWAL: 140 dam^3

SOURCE: Aquifer
LOCATION: Medley River

SURFACE RETURN FLOWS: 0

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR)	SOURCE	SURFACE RETURN (dam^3/YR.)	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)
1985	140	Aquifer	0	140	Aquifer	0
2000	460*	Aquifer	28	1740*	Cold Lake or Aquifer	104
2015	460*	Aquifer	28	1740*	Cold Lake or Aquifer	104

COMMENTS:

* Assuming that 50% of total water requirement is met with recycled produce water.

Surface return water from backwash assumed to be equal to 3 % of total water requirements.

Produce water effluent to be deep injected in or below the formation.

WATER USERS NAME: Petro Canada Exploration Inc.
REACH NUMBER: 223

PRESENT USE:

1980 WITHDRAWAL: 55 dam^3

SOURCE: Muriel Lake
LOCATION: Muriel Lake

SURFACE RETURN FLOW:

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR)	SOURCE	SURFACE RETURN (dam^3/YR.)	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)
1985	250	Muriel Lake	0	280	Muriel Lake	0
2000	250	Muriel Lake	0	1190*	Unknown (surface water?)	71
2015	0	-	-	640*	Unknown (surface water?)	33

COMMENTS:

* Assuming that 50% of total water requirement is met with recycled produce water.

Surface return water from backwash assumed to be equal to 3 % of total water requirements.

Produce water effluent to be deep injected in or below the formation.

Oil sand production phasing out by year 2015.

WATER USERS NAME: Suncor Inc. Resources Group
REACH NUMBER: 525

PRESENT USE:

1980 WITHDRAWAL: 330 dam^3

SOURCE: Aquifer
LOCATION: Ft. Kent

SURFACE RETURN FLOW:

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR)	SOURCE	SURFACE RETURN (dam^3/YR.)	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)
1985	1040*	Bonnyville Sewage lagoon	0	1040*	Bonnyville Sewage lagoon	0
2000	1740**	Probably N. Sask. river	105	3480**	Probably N. Sask. river	210
2015	0	-	-	0	-	-

COMMENTS:

Fresh water make-up supplied by Bonnyville Sewage Lagoon effluent.

Assuming that 10%(*) and 50%(**) of total water requirement is met with recycled produce water.

Surface return water from backwash assumed to be equal to 3 % of total water requirements.

Produce water effluent to be deep injected in or below the formation.

Oil sand finished by year 2015.

WATER USERS NAME: Union Texas of Canada (Drummond Petroleum Ltd.)
REACH NUMBER: 526

PRESENT USE:

1980 WITHDRAWAL: 67 dam^3

SURFACE RETURN FLOW: 0

SOURCE: Aquifer
LOCATION: Beaver River

FUTURE USE:

	LOW DEVELOPMENT			HIGH DEVELOPMENT		
YEAR	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)	WITHDRAWAL (dam^3/YR.)	SOURCE	SURFACE RETURN (dam^3/YR.)
1985	130	Aquifer	0	180	Aquifer	0
2000	130	Aquifer	0	730	Unknown (surface water?)	0
2015	130	Aquifer	0	730	Unknown (surface water?)	0

COMMENTS:

Future uses assume all produce water will be recycled. Make up water required only to replace the produce oil (replacement ratio of 1.25).

No allowance made for backwash/blowdown water.

APPENDIX F

POTENTIAL AND PROPOSED DUCKS UNLIMITED PROJECTS IN THE BEAVER RIVER BASIN

POTENTIAL PROJECTS

NAME	ACRES	LAND LOCATION	WATER LEVEL	COMMENTS
HUPPIE LK.	1680	17,18,19,20,30-64-12W4 23,24,25,26-64-13W4	1'-2' LOWER	
DESMAW LK.	259	36-63-14W4 6-64-13W4	1' LOWER	
RICH LK.	1760	1,11,12,12-64-11W4 14,23,24,26-64-11W4 31-62-10W4 6-64-10W4	VARIABLE	DRAWDOWN
	185	12,13,14,23-61-11W4	VARIABLE	DRAWDOWN
CROOKED LK.	361	7,18-63-7W4 13,24-63-8W4	LOWER	VARIABLE
THIN LK.	170	19,20,29-60-7W4	LOWER	
	35	11-61-6W4	MAINTAIN	VARIABLE
KEITH LK.	480	15,16-64-8W4	LOWER	DRAWDOWN
BARBARA LK.	1135	4,5,6,8,9-64-6W4 15,16,17,18-64-6W4	LOWER	VARIABLE
OSBORNE LK.	884	31,32-63-6W4 36-63-7W4	LOWER	VARIABLE
	272	5,6-64-5W4	LOWER	DRAWDOWN
	324	32,33-61-5W4 4,5-62-5W4	1'-1.5' LOWER	
LANDRY LK.	260	23,24,25,26-60-5W4	MAINTAIN	VARIABLE
	65	3,4,9,10-61-4W4	LOWER	DRAWDOWN
	208	14,15,22-61-4W4	LOWER	DRAWDOWN
	32	28,33-60-2W4	MAINTAIN	DRAWDOWN
	95	26-60-12-W4	1'-2' LOWER	

PROPOSED PROJECTS

MANATOKAN LK.	2375	22,23,26,27-63-7W4 13,14,23,24-63-7W4 16,17,20,21-63-6W4	MAINTAIN
GOODFISH LK.	3852	61-13W4, 61-12W4	MAINTAIN
REED LK.	2036	60-12W4, 61-12W4	1'-1.5' LOWER

APPENDIX E

WATER BALANCE MODEL

A Report Prepared By
NANUK ENGINEERING & DEVELOPMENT LTD.

April 6, 1983

Alberta Environment
Planning Division
9820 106 Street
Edmonton, Alberta
T5K 2J6

Attention: Mr. Jim Snidal
Water Resources Planning Engineer
Athabasca River Basin

RE: Beaver River-Cold Lake Regional Water Resources Study
Water Balance Model

Dear Jim;

Nanuk Engineering & Development is pleased to submit the final report on the use of the water balance simulation model for the above described study. The interaction of our modelling team with other study components, and study management, made the use of the model very effective. Certainly, we appreciated the opportunity to participate in this study.

The report has been written to inform and document but more importantly to form a base for future more detailed work in the Region. A good hydrologic data base has been established on government computing facilities. The limitations and potential of water resource development in the Region have been determined. Future work can focus on specific projects.

The results of selected simulations presented in the report represent only a small fraction of those performed. Summaries of the results from all simulations are available from Planning Division, Alberta Environment or Nanuk Engineering.

Yours truly,

MVThompson

M. V. Thompson, P. Eng.
Chief Engineer

MVT:lc
attachment

BEAVER RIVER-COLD LAKE
REGIONAL WATER RESOURCES STUDY
WATER BALANCE MODEL

TABLE OF CONTENTS

PAGE #

I. SYNOPSIS

1. INTRODUCTION 1.1
   1.1 PURPOSE 1.1
   1.2 RELATIONSHIP TO STUDY COMPONENTS 1.3
   1.3 MODELLING STRATEGY 1.6

2. MODEL STRUCTURE 2.1
   2.1 ELEMENTS OF THE PHYSICAL SYSTEM 2.1
   2.2 WATER USES AND PROCESSES 2.1
   2.3 SYSTEM OPERATING PROCEDURES 2.5
   2.4 INPUT DATA AND OUTPUT 2.6
   2.5 MODEL CAPABILITY AND ACCURACY 2.9
   2.6 TECHNOLOGY TRANSFER 2.12

3. TESTING OF MODEL & INITIAL BASIN ANALYSIS 3.1
   3.1 NATURAL FLOW SIMULATION 3.1
   3.2 SIMULATION OF 2015 WATER DEMAND SCENARIO 3.2
      3.2.1 BASIS OF SIMULATION 3.2
      3.2.2 SIMULATION RESULTS 3.5
   3.3 WATER QUALITY FLOWS 3.7

4. SUB-BASIN ANALYSES 4.1
   4.1 GENERAL 4.1
   4.2 OPERATING CRITERIA 4.2
      4.2.1 LAKE LEVEL CRITERIA 4.2
      4.2.2 STREAMFLOW CRITERIA 4.4
   4.3 REGULATION ALTERNATIVES 4.7

TABLE OF CONTENTS
(CONTINUED)

PAGE #

4.4 WOLF RIVER 4.9
4.5 MANATOKAN CREEK 4.9
4.6 MARIE CREEK 4.12
4.7 COLD LAKE 4.28
4.8 MOOSELAKE RIVER 4.33
4.9 MURIEL CREEK 4.37
4.10 CARIBOU LAKE 4.37
4.11 REITA CREEK 4.40
4.12 SYSTEM SIMULATION: UNATTENDED OUTLETS 4.43
4.13 SYSTEM SIMULATION: FULLY CONTROLLED OUTLETS 4.47

5. SAND RIVER RESERVOIR 5.1

5.1 GENERAL 5.1
5.2 OPERATING CRITERIA 5.1
5.3 SIMULATION RESULTS 5.3
5.4 SUMMARY 5.4

6. REGIONAL MANAGEMENT ALTERNATIVES 6.1

6.1 INTRODUCTION 6.1
6.2 SHORT TERM ALTERNATIVE 6.2
6.3 INTERMEDIATE TERM ALTERNATIVES 6.6
  6.3.1 LOCAL SUPPLY 6.6
  6.3.2 SAND RIVER RESERVOIR 6.10
  6.3.3 IMPORT WATER 6.14
6.4 LONG TERM ALTERNATIVES 6.17
  6.4.1 LOCAL SUPPLY 6.17
  6.4.2 SAND RIVER RESERVOIR 6.21
  6.4.3 IMPORT WATER 6.25

PLATES

TABLE OF CONTENTS

APPENDICES

APPENDIX A TERMS OF REFERENCE

APPENDIX B DATA FOR MODEL

APPENDIX C CHARACTERISTICS OF UNATTENDED OUTLETS

TABLE OF CONTENTS

FIGURES

		PAGE #
FIGURE 1.1	KEY MAP	1.2
FIGURE 1.3	AREA MAP	1.7
FIGURE 2.1	WATER BALANCE MODEL SCHEMATIC	2.2
FIGURE 2.4	WATER BALANCE MODEL STANDARD PRINTOUT	2.10
FIGURE 4.2.2	CUMULATIVE FREQUENCY DISTRIBUTION WOLF RIVER D/W WOLF LAKE MARCH FLOWS	4.5
FIGURE 4.12	WATER BALANCE MODEL SCHEMATIC SYSTEM SIMULATION MAXIMUM WITHDRAWAL WITH UNATTENDED OUTLETS	4.43
FIGURE 4.13	WATER BALANCE MODEL SCHEMATIC SYSTEM SIMULATION MAXIMUM WITHDRAWAL WITH FULLY CONTROLLED OUTLETS	4.48
FIGURE 6.2.1	WATER BALANCE MODEL SCHEMATIC REGIONAL MANAGEMENT ALTERNATIVE SHORT TERM	6.3
FIGURE 6.3.1	WATER BALANCE MODEL SCHEMATIC REGIONAL MANAGEMENT ALTERNATIVE INTERMEDIATE TERM - LOCAL SUPPLY	6.7
FIGURE 6.3.2	WATER BALANCE MODEL SCHEMATIC REGIONAL MANAGEMENT ALTERNATIVE INTERMEDIATE TERM - SAND RESERVOIR	6.11
FIGURE 6.3.3	WATER BALANCE MODEL SCHEMATIC REGIONAL MANAGEMENT ALTERNATIVE INTERMEDIATE TERM - IMPORT WATER	6.15
FIGURE 6.4.1	WATER BALANCE MODEL SCHEMATIC REGIONAL MANAGEMENT ALTERNATIVE LONG TERM - LOCAL SUPPLY	6.18
FIGURE 6.4.2	WATER BALANCE MODEL SCHEMATIC REGIONAL MANAGEMENT ALTERNATIVE LONG TERM - SAND RESERVOIR	6.22
FIGURE 6.4.3	WATER BALANCE MODEL SCHEMATIC LONG TERM - IMPORT WATER	6.26

Table of Contents

Tables

		Page #
Table 1.2.1	Type I Summary	1.4
Table 1.2.2	Type II Summary	1.5
Table 2.1	Simulated Elements of Physical System	2.3
Table 3.1.1	Comparison of Recorded & Simulated Natural Flows BEAVER RIVER AT COLD LAKE RESERVE	3.3
Table 3.1.2	Comparison of Recorded & Simulated Natural Flows SAND RIVER AT TRUMAN	3.4
Table 3.2.2.1	Annual Flows BEAVER RIVER AT SASKATCHEWAN BORDER	3.6
Table 3.2.2.2	% Reduction in Monthly Median Streamflows: NATURAL/DEVELOPED YEAR 2015 HIGH DEVELOPMENT SCENARIO	3.8
Table 3.2.2.3	Annual Shortages at Major Withdrawals YEAR 2015 HIGH DEVELOPMENT SCENARIO	3.9
Table 3.2.2.4	Annual Median Lake Levels: Natural/Developed YEAR 2015 HIGH DEVELOPMENT SCENARIO	3.10
Table 3.3.1	Flows for Simulation Week Ending 7 Oct 67 YEAR 2015 HIGH DEVELOPMENT SCENARIO	3.12
Table 3.3.2	Weekly Low Flows from Natural Simulation	3.13
Table 4.2.1	Preferred/Acceptable Lake Levels (METERS A.S.L.)	4.3
Table 4.2.2	Minimum Acceptable Flow Levels	4.6
Table 4.4.1	Wolf Lake Simulation Summary UNATTENDED OUTLET	4.10
Table 4.4.2	Wolf Lake Simulation Summary FULLY CONTROLLED OUTLET	4.11
Table 4.5.1	Manatokan Lake Simulation Summary UNATTENDED OUTLET	4.13
Table 4.5.2	Manatokan Lake Simulation Summary DUCKS UNLIMITED OUTLET	4.14

TABLES (CONTINUED)

		PAGE #
TABLE 4.6.1	BURNT LAKE SIMULATION SUMMARY UNATTENDED OUTLET	4.15
TABLE 4.6.2	MAY LAKE SIMULATION SUMMARY EXISTING OUTLET	4.16
TABLE 4.6.3	MARIE LAKE SIMULATION SUMMARY EXISTING OUTLET	4.17
TABLE 4.6.4	ETHEL LAKE SIMULATION SUMMARY EXISTING OUTLET	4.18
TABLE 4.6.5	BURNT LAKE SIMULATION SUMMARY FULLY CONTROLLED OUTLET	4.19
TABLE 4.6.6	MAY LAKE SIMULATION SUMMARY EXISTING OUTLET	4.20
TABLE 4.6.7	MARIE LAKE SIMULATION SUMMARY EXISTING OUTLET	4.21
TABLE 4.6.8	ETHEL LAKE SIMULATION SUMMARY EXISTING OUTLET	4.22
TABLE 4.6.9	MARIE LAKE SIMULATION SUMMARY UNATTENDED OUTLET	4.23
TABLE 4.6.10	ETHEL LAKE SIMULATION SUMMARY EXISTING OUTLET	4.24
TABLE 4.6.11	MARIE LAKE SIMULATION SUMMARY FULLY CONTROLLED OUTLET	4.25
TABLE 4.6.12	ETHEL LAKE SIMULATION SUMMARY EXISTING OUTLET	4.26
TABLE 4.6.13	ETHEL LAKE SIMULATION SUMMARY UNATTENDED OUTLET	4.27
TABLE 4.7.1	COLD LAKE SIMULATION SUMMARY EXISTING OUTLET	4.30
TABLE 4.7.2	COLD LAKE SIMULATION SUMMARY UNATTENDED OUTLET	4.31
TABLE 4.7.3	COLD LAKE SIMULATION SUMMARY FULLY CONTROLLED OUTLET	4.32
TABLE 4.8.1	MOOSE LAKE SIMULATION SUMMARY UNATTENDED OUTLET	4.34
TABLE 4.8.2	MOOSE LAKE SIMULATION SUMMARY FULLY CONTROLLED OUTLET	4.35

Tables (continued)

		Page #
Table 4.10.1	Caribou Lake Simulation Summary UNATTENDED OUTLET	4.38
Table 4.10.2	Caribou Lake Simulation Summary FULLY CONTROLLED OUTLET	4.39
Table 4.11.1	Angling Lake Simulation Summary UNATTENDED OUTLET	4.41
Table 4.12.1	System Simulation MAXIMUM WITHDRAWALS WITH UNATTENDED OUTLETS BEAVER RIVER D/S REITA CREEK	4.44
Table 4.12.2	System Simulation MAXIMUM WITHDRAWALS WITH UNATTENDED OUTLETS SAND RIVER AT MOUTH	4.45
Table 4.13.1	System Simulation MAXIMUM WITHDRAWALS FULLY CONTROLLED OUTLETS BEAVER RIVER D/S REITA CREEK	4.49
Table 4.13.2	System Simulation MAXIMUM WITHDRAWALS FULLY CONTROLLED OUTLETS SAND RIVER AT MOUTH	4.50
Table 5.3.1	Potential Reservoir on Sand River SIMULATION SUMMARY CRITERIA #1	5.3
Table 5.3.2	Potential Reservoir on Sand River SIMULATION SUMMARY CRITERIA #2	5.5
Table 5.3.3	Potential Reservoir on Sand River SIMULATION SUMMARY CRITERIA #3	5.6
Table 6.2.1	System Simulation REGIONAL MANAGEMENT ALTERNATIVE SHORT TERM BEAVER RIVER D/S REITA CREEK	6.4
Table 6.2.2	System Simulation REGIONAL MANAGEMENT ALTERNATIVE SHORT TERM SAND RIVER AT MOUTH	6.5
Table 6.3.1.1	System Simulation REGIONAL MANAGEMENT ALTERNATIVE INTERMEDIATE TERM - LOCAL SUPPLY BEAVER RIVER D/S REITA CREEK	6.8
Table 6.3.1.2	System Simulation REGIONAL MANAGEMENT ALTERNATIVE INTERMEDIATE TERM - LOCAL SUPPLY SAND RIVER AT MOUTH	6.9

TABLES (CONTINUED) PAGE #

TABLE 6.3.2.1	SYSTEM SIMULATION REGIONAL MANAGEMENT ALTERNATIVE INTERMEDIATE TERM - SAND RESERVOIR BEAVER RIVER D/S REITA CREEK	6.12
TABLE 6.3.2.2	SYSTEM SIMULATION REGIONAL MANAGEMENT ALTERNATIVE INTERMEDIATE TERM - SAND RESERVOIR SAND RIVER AT MOUTH	6.13
TABLE 6.3.3.1	SYSTEM SIMULATION REGIONAL MANAGEMENT ALTERNATIVE INTERMEDIATE TERM - IMPORT WATER BEAVER RIVER D/S REITA CREEK	6.16
TABLE 6.4.1.1	SYSTEM SIMULATION REGIONAL MANAGEMENT ALTERNATIVE LONG TERM - LOCAL SUPPLY BEAVER RIVER D/S REITA CREEK	6.19
TABLE 6.4.1.2	SYSTEM SIMULATION REGIONAL MANAGEMENT ALTERNATIVE LONG TERM - LOCAL SUPPLY SAND RIVER AT MOUTH	6.20
TABLE 6.4.2.1	SYSTEM SIMULATION REGIONAL MANAGEMENT ALTERNATIVE LONG TERM - SAND RESERVOIR BEAVER RIVER D/S REITA CREEK	6.23
TABLE 6.4.2.2	SYSTEM SIMULATION REGIONAL MANAGEMENT ALTERNATIVE LONG TERM - SAND RESERVOIR SAND RIVER AT MOUTH	6.24
TABLE 6.4.3.1	SYSTEM SIMULATION REGIONAL MANAGEMENT ALTERNATIVE LONG TERM - IMPORT WATER BEAVER RIVER D/S REITA CREEK	6.27

LIST OF PLATES

3.1.1	Simulated Natural Flows; Beaver River @ Cold Lake Reserve
3.1.2	Simulated Natural Flows; Sand River @ Truman
3.1.3	Simulated Natural Levels; Cold Lake
3.1.4	Simulated Natural Levels; Wolf Lake
3.1.5	Simulated Natural Levels; Wolf River @ Wolf Lake
3.2.1	Year 2015, High Development Scenario, Natural and Developed Levels, Wolf Lake
3.2.2	Year 2015, High Development Scenario, Natural and Developed Flows, Wolf River @ Wolf Lake
4.4	Wolf Lake; Sub-Basin Analysis
4.5	Manatokan Lake; Sub-Basin Analysis
4.6.1	Burnt Lake; Sub-Basin Analysis
4.6.2	Marie Lake; Sub-Basin Analysis
4.6.3	Ethel Lake; Sub-Basin Analysis
4.7	Cold Lake; Sub-Basin Analysis
4.8	Moose Lake; Sub-Basin Analysis
4.10	Caribou Lake; Sub-Basin Analysis
4.11	Angling Lake; Sub-Basin Analysis
4.12	System Simulations; Beaver and Sand River Flows

LIST OF PLATES (CONTINUED)

5.4 SIMULATED FLOWS AND LEVELS; SAND RIVER RESERVOIR

6.2 SHORT TERM ALTERNATIVE; BEAVER AND SAND RIVER FLOWS

6.3 INTERMEDIATE TERM ALTERNATIVES; BEAVER AND SAND RIVER FLOWS

6.4 LONG TERM ALTERNATIVES; BEAVER AND SAND RIVER FLOWS

i. Synopsis

The water balance model was used for the evaluation of water resource management alternatives in the Beaver River-Cold Lake Region. The potential development of oil sands will increase the consumptive use of water in the Region. The maintenance of acceptable regimes for lakes and streams with increased water usage requires an accurate assessment of the long term affects of industrial withdrawals. The water balance model simulated the affects of changes in the water resource system by superimposing future withdrawals, and structural changes on the natural flows in the Region for the period 1956 to 1981. The results of the simulation were used to assess, and modify water management alternatives.

The stages of model usage were;

- set-up and verification
- maximum withdrawal simulation
- simulation of sub-basins to determine maximum permissible withdrawals
- analysis of a potential storage reservoir on the Sand River
- simulation of regional management alternatives

The report describes the nature of the model and its usage. Selected results are presented in graphical and tabular form. Observations are made on significance of the simulation results and suggestions are offered for improvement of alternatives but conclusions and recommendations are left for others.

SECTION 1

INTRODUCTION

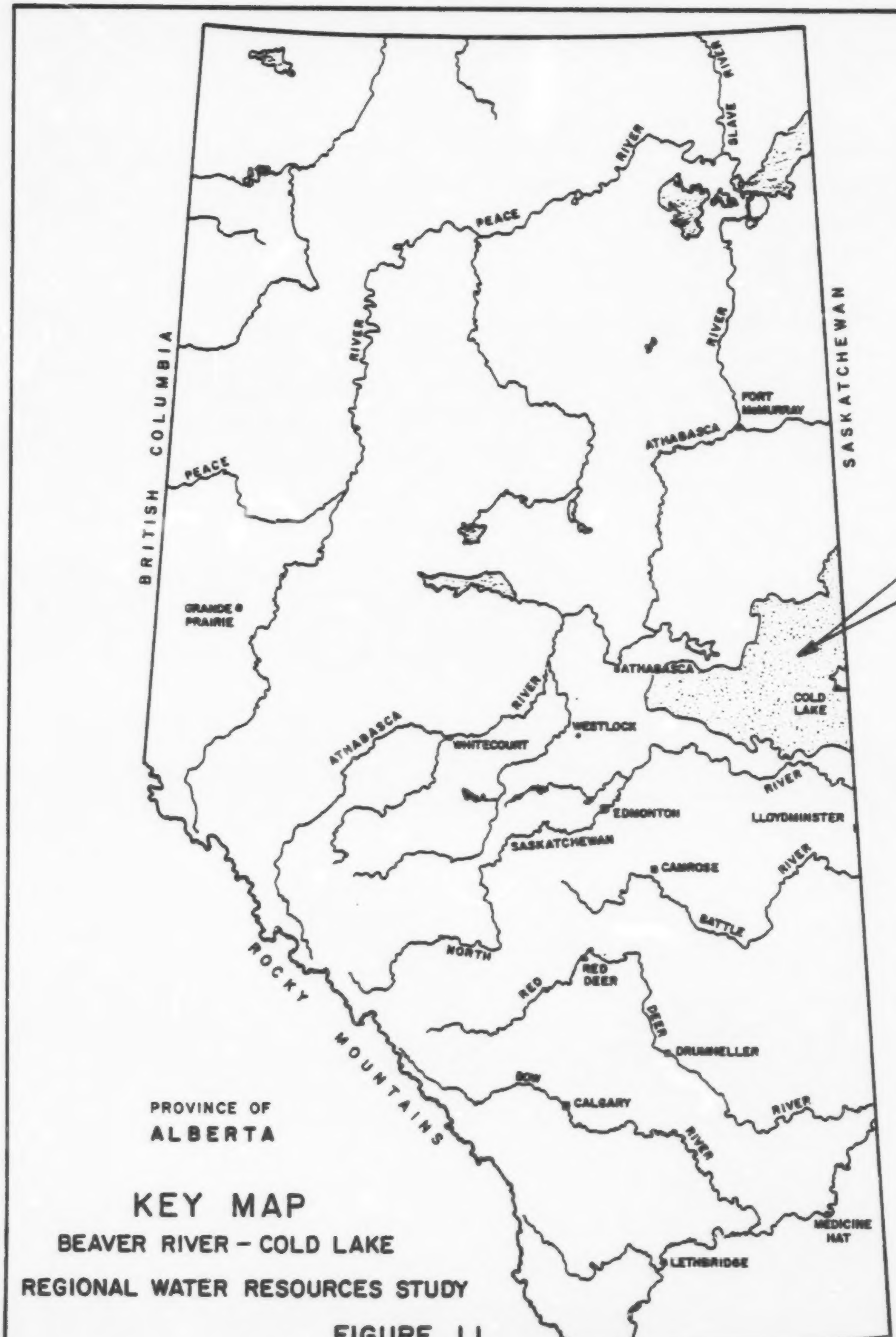
1. INTRODUCTION

1.1 PURPOSE

The management of the surface and ground water resources in the Beaver River - Cold Lake Region of north-eastern Alberta (Figure 1.1) requires knowledge of the water supply and insight into the current uses and future demands on the water resource system. The impetus of rapid economic growth in this region, associated with the development of heavy oil extraction plants led Alberta Environment to commission a multi-component study of water resources in the region. The use of a water balance model to evaluate the effects of various water demand scenarios without, and with, structural modifications to the basin was one component study.

The specific terms of reference for the water balance component were:

- develop specifications for the model, describing the model structure, input data and output, modelled elements of the physical system, water uses and processes simulated and operating policies that can be considered
- test the model such that all of the model components are utilized; ensure satisfactory operation; test the model to assess its accuracy and present the results for review and approval
- set up the model on the Alberta Government computing system for operation on the entire study area, test to ensure satisfactory operation over the hydrologic study period 1956 to 1981 and familiarize representatives of Alberta Environment with the model's operation
- simulate a weekly water balance over the hydrologic period of record, 1956 to 1981, for the water demand scenarios forecasted for the year 1985, 2000 and 2015.
- using water supply and use management alternatives identified by Alberta Environment, simulate a weekly water balance to evaluate the impacts/benefits of the alternatives


SLAVE RIVER
PEACE RIVER
PEACE
RIVER
BRITISH COLUMBIA
SASKATCHEWAN
RIVER
FORT McMURRAY
ATHABASCA
PEACE
GRANDE PRAIRIE
STUDY AREA
ATHABASCA
COLD LAKE
RIVER
ATHABASCA
WESTLOCK
WHITECOURT
RIVER
EDMONTON
LLOYDMINSTER
SASKATCHEWAN
CAMROSE
RIVER
BATTLE
NORTH
ROCKY MOUNTAINS
RED DEER
RED
DEER
DRUMHELLER
BOW
CALGARY
RIVER
RIVER
MEDICINE HAT
LETHBRIDGE
PROVINCE OF
ALBERTA

KEY MAP
BEAVER RIVER - COLD LAKE
REGIONAL WATER RESOURCES STUDY

FIGURE 1.1

1.2 RELATIONSHIP TO STUDY COMPONENTS

The water balance model component integrated the findings of several study components and produced data and analysis for assessment in other components. Basic contributors of data to the model were withdrawal water demands, surface water supply and water-based recreation. The Study Team, Instream Water Users Subcommittee, water quality study component and Planning Division used the simulated flows and lake levels from the model to evaluate the effects of water withdrawals and structural and operational changes to the water resource system.

The model was configured and the output subroutines programmed to provide results which were compatible with the needs of the user groups and the data produced by other components. Two different summary tables were derived. Tables 1.2.1 and 1.2.2 are examples of the two types of summaries. Flow and lake level variations were plotted to supplement the summary tables. Examples of these graphs are provided in Section 4 'Sub-Basin Analyses'. The model was also configured to permit direct extraction of flow data for use in a special purpose, water quality computer model.

Although interaction with the study group was continuous during the study period, several salient tasks worthy of note, are;

- Water Supply - manipulation of hydrologic data for storage in a standard format and subsequent use in the water balance model
- Water Quality - statistical analysis of monthly mean flows and 1 in 10 year, weekly low flows for the high withdrawal scenario for selected reaches
- Instream Water User's Subcommittee - presentation and discussion of simulation results and determination of lake level and stream flow criteria
- Planning Division - analysis of low flows for use in water quality model

TABLE 1.2.1

TYPE I SUMMARY

COLD LAKE/BEAVER RIVER STUDY

CARIBOU Lake Management SYSTEM 1B Scenario

Stage-Discharge Curve UNATTENDED OUTLET

Minimum D/S Flow Winter: 40 % Summer: 25 %

Industrial Withdrawal 0.2 ≥ 632.85 cms

		Regulated Flow	Natural Flow	Change
Mean Lake Level(m)	Long Term	633.40	633.22	+ 0.18
	Winter	633.16	633.13	+ 0.03
	S.D.	0.286	0.128	+123.4 %
	Summer	633.77	633.32	+ 0.45
	S.D.	0.330	0.183	+ 80.3 %
Maximum Lake Level(m)		634.78	634.38	+ 0.40
% of Time Level > 633.98 m				
	Long Term	7.6	0.3	+ 7.3 %
	Winter	0.7	0.0	+ 0.7 %
	Summer	14.5	0.6	+ 13.9 %
Flows				
Average of Annual Maxima		23.57	23.21	+ 1.6 %
Average of Annual Minima		0.26	0.44	- 4.09 %
Absolute Minimum		0.00	0.03	- 0.03
Minimum Flow Achieved (%)				
	Winter	55.5	62.1	- 6.6 %
	Summer	72.5	74.4	- 1.9 %
Average Annual Deficit (%)				
	Long Term	0.44		
	Winter	0.87		
	Summer	0.00		

DATE: Nov 17, 1982

TABLE 1.2.2

TYPE II SUMMARY

LOCATION CARIBOU LAKE
MANAGEMENT SCENARIO SYSTEM 1B
DATE Nov 16, 1982
REGULATION CONDITION UNATTENDED OUTLET
WITHDRAWAL 0.2 cms ≥ 632.85
RUN NO. SYSTEM 1B

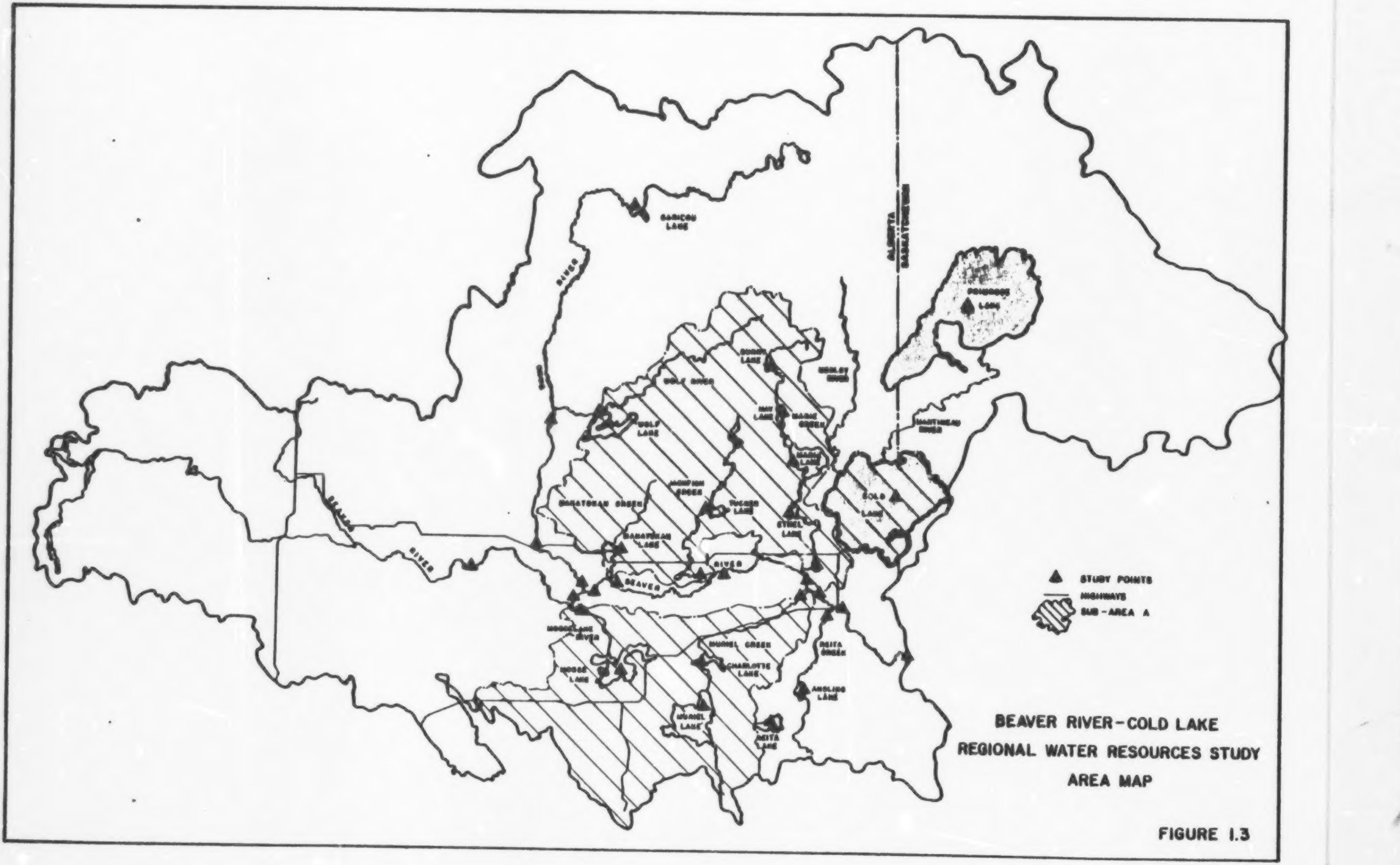
	PREFERRED-ACCEPTABLE VALUE			SIMULATION VALUES		% OF TIME PREFERRED VALUE EXCEEDED					
						Natural			Regulated		
	Fish/Wildlife	Recreation	Withdrawal	Natural	Regulated	L	W	S	L	W	S
LAKE LEVELS (m)											
Maximum				634.38	634.78						
10% Exceedance	633.98			633.48	633.96	0.3	0.0	0.6	7.6	0.7	14.5
Mean (Median)	633.72			633.22	633.41	1.8	0.0	3.6	32.3	11.7	52.8
90% Exceedance	633.02			633.02	633.04	89.6	81.4	97.9	92.0	84.9	99.1
Minimum	632.85			632.85	632.85	100.0	100.0	100.0	99.2	98.4	100.0
RIVER FLOWS (cms)	40%-25% PMF			ABSOLUTE MINIMUM							
Jan	0.71			0.08	0.01	60.3			53.9		
Feb	0.58			0.05	0.00	59.1			46.8		
Mar	0.47			0.04	0.00	57.8			36.4		
Apr	2.49			0.25	0.01	56.3			41.7		
May	3.36			0.50	0.50	78.0			77.3		
Jun	2.37			0.44	0.32	75.6			78.1		
Jul	1.58			0.72	0.59	78.5	62.1	74.4	80.5	55.5	72.5
Aug	1.70			0.45	0.24	75.4			74.6		
Sep	1.12			0.39	0.18	81.2			80.3		
Oct	1.50			0.49	0.29	78.3			76.6		
Nov	1.89			0.20	0.05	60.9			63.6		
Dec	1.16			0.10	0.01	56.3			56.3		
Absolute Minimum				0.03	0.00						
Mean Annual Minima				0.44	0.26						
Mean Annual Maxima				23.21	23.57						
Absolute Maxima				90.29	88.93						
WITHDRAWAL											
Deficit (%)					0.44						
(Dam³)/Year					27.63						
Deficit > 10%											
% of Time					0.81						
Maximum Duration (weeks)					7						
Associated deficit (dam³)					609.02						
Deficit > 30%											
% of Time					0.52						
Maximum Duration (weeks)					6						
Associated deficit (dam³)					573.61						

The water balance model was a focal point for the study. The data, operating criteria, and concepts developed by various study components were input to the model and the effects of the changes to the water produced by the simulation program. The study team assessed the results, and refinements were made to operating criteria, procedures and the methods of presentation of the summary data. The water balance model provided consistency and organization to the integration of the study data and results.

1.3 MODELLING STRATEGY

The basic function of the computer model was to simulate the surface water system within the Beaver River-Cold Lake Region by calculating the water balance, i.e., the difference between water supply and water used, along river reaches, at points of major water demands, and within lakes. These study points, as used in the model are illustrated on Figure 1.3. Water supply was represented by the natural, surface water runoff between the year 1956 and 1981. A basic tenet of model use was that the flows within this period are representative of hydrologic cycles that will occur in the future. Future streamflows and lake levels will be affected by the increased withdrawal of water and the structures and operating procedures which may be required to permit the withdrawals. The water balance model provides a means of assessing these affects by superimposing alternative water management schemes on the historical water supply.

The water balance model uses a network analogy to represent the surface water system. Nodes are lakes, reservoirs, study points or junctions of rivers. The links or arcs between the nodes are river reaches, diversion canals or return flow channels. The model of the river and lake system is an assemblage of basic simulation components, such as a lake, river reach, control structure, diversion channel and point of water consumption. The hydrologic processes of water storage, flow, evaporation, precipitation and consumption take place in the simulation components. The nodes and arcs of the network are designated


STUDY POINTS
HIGHWAYS
SUB-AREA A
ALBERTA
SASKATCHEWAN
PRIMROSE LAKE
MARTINEAU RIVER
COLD LAKE
WOLF LAKE
WOLF RIVER
MAY LAKE
MARIE CREEK
MARIE LAKE
TUCKER LAKE
ETHEL LAKE
MANATOKAN LAKE
BEAVER
RIVER
MOOSELAKE RIVER
MOOSE LAKE
MURIEL CREEK
CHARLOTTE LAKE
MURIEL LAKE
REITA CREEK
REITA LAKE
ANGLING LAKE

BEAVER RIVER-COLD LAKE
REGIONAL WATER RESOURCES STUDY
AREA MAP

FIGURE 1.3

as the components of the system and since they can be assembled into any form of network, the model allows quick and easy adjustment of the level of detail and the number of physical system components represented. The model can simulate the river system on a daily basis or any integer multiple of days.

The strategy adopted for use of the model on the Beaver River - Cold Lake Region was;

1. Simulate the entire region on a weekly and monthly basis to;
   a. confirm the validity of the model
   b. evaluate the effect of the highest projected water demand for the year 2015 on the regional water resource
   c. provide initial data for analysis of in-stream flows and set-up of the water quality model.
2. Simulate the various sub-basins within the Region to evaluate maximum potential water withdrawal using unattended and fully controlled outlet structures which satisfy stream flow and lake level guidelines. The sub-basins identified for these evaluations were;
   a. Wolf River
   b. Manatokan Creek
   c. Marie Creek including, Burnt, May, Marie and Ethel Lakes
   d. Cold Lake
   e. Mooselake River
   f. Muriel Creek above Charlotte Lake
   g. Reita Creek including Reita and Angling Lakes
   h. Sand River above the Wolf River
3. Develop operating criteria and evaluate the effects of a large withdrawal from a potential reservoir on the Sand River below the confluence with the Wolf.
4. Combine the best management alternatives for the sub-basins with projected near, intermediate and long term water demands for a simulation of the full region and evaluate overall effects on the flows in the main stem of the Beaver River, lower Sand, and to Saskatchewan.

This report describes the nature of the computer simulations, the associated data and assumptions, and operating policy. The simulation results are presented in summary and graphical format. Observations on each simulation and suggestions for improvement of the operating policy and/or structural modification of the water supply system are made.

SECTION 2

MODEL STRUCTURE

2. MODEL STRUCTURE

2.1 ELEMENTS OF THE PHYSICAL SYSTEM

The extent of the study area is shown in Figure 1.3. Since the primary emphasis of the study was on sub-area A, the water balance model was configured to provide detailed simulation of the Beaver and its tributaries along the main stem. The Beaver River was not modelled above Goodridge. The Sand River was simulated in moderate detail with study points at the mouth, Truman, Wolf River confluence and Caribou Lake. The Cold River basin was initially simulated at Cold Lake, Primrose Lake, and the Medley and Cold Rivers and later reduced to Cold Lake and the Cold River when Primrose Lake was not considered for regulation or withdrawal.

Figure 2.1 is a schematic of the river basin system used in the water balance model. The schematic displays a network of nodes and arcs which represent the physical system and location of withdrawals for the 2015 development scenario. Water is simulated to flow on a weekly or monthly basis from the nodes where inflow occurs into the lakes, to rivers and points of withdrawal or to Saskatchewan. The basic elements of the physical system which were simulated are;

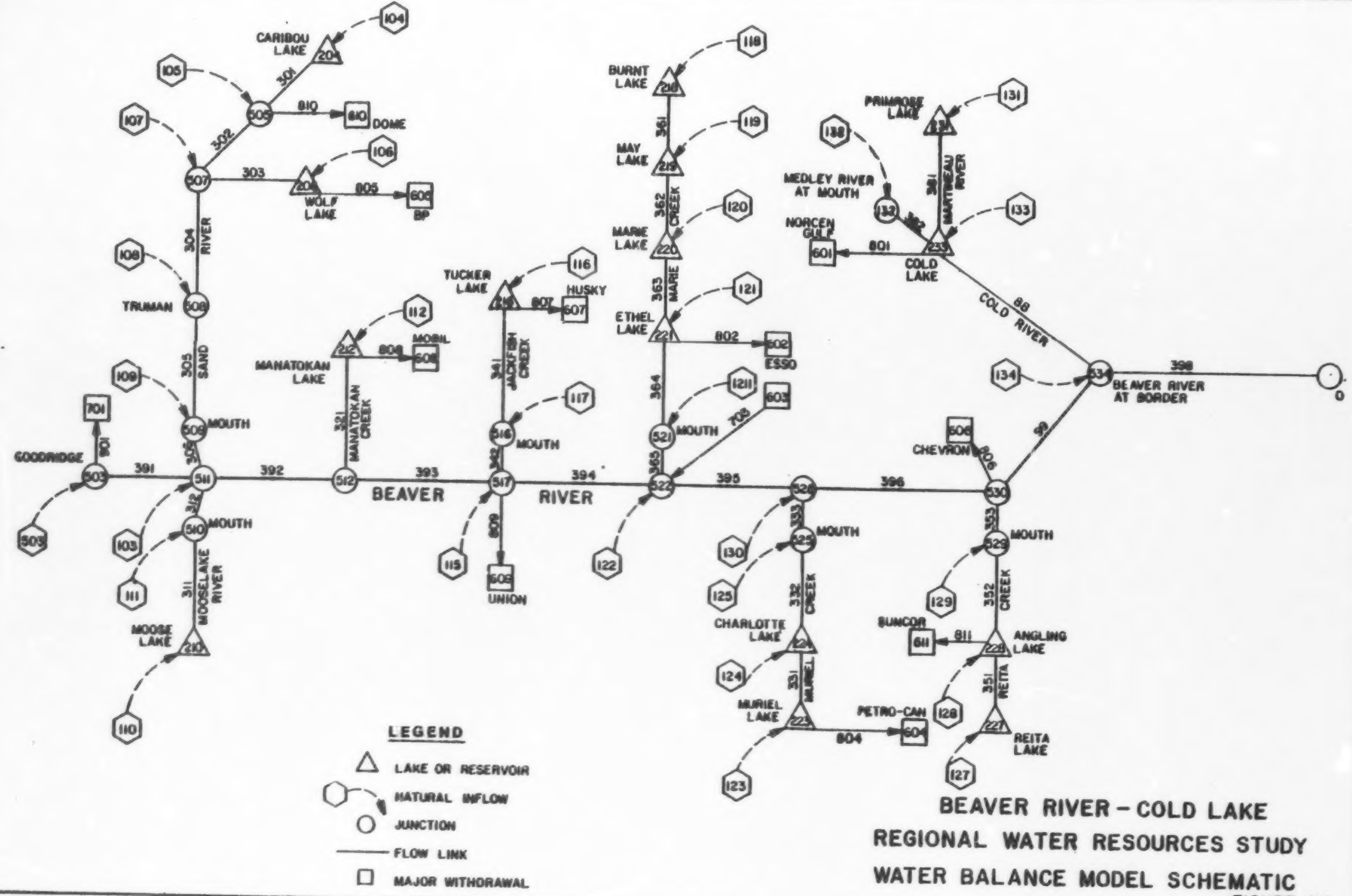
a. lakes with natural or regulated outlets
b. potential storage reservoirs
c. local runoff from sub-basin watersheds
d. river reaches
e. points of withdrawal and consumption of water
f. confluence of rivers

In particular the model produced simulated flows or elevations for the elements of surface water system in the Region displayed in Table 2.1.

2.2 WATER USES AND PROCESSES

There are a variety of water uses within the Region including:

- domestic
- municipal
- irrigation diversions
- recreation use of lakes and streams
- industrial withdrawals
- sewage effluent assimilation


CARIBOU LAKE
204
104
105
301
505
810
610
DOME
107
302
507
303
106
204
WOLF LAKE
805
605
BP
304
RIVER
108
TRUMAN
508
305
SAND
109
509
MOUTH
701
901
GOODRIDGE
503
391
306
511
392
512
BEAVER
393
517
RIVER
394
522
395
526
396
530
398
534
BEAVER RIVER AT BORDER
0
503
312
103
510
MOUTH
111
311
MOOSELAKE RIVER
MOOSE LAKE
210
110
MANATOKAN LAKE
212
112
808
608
MOBIL
321
MANATOKAN CREEK
TUCKER LAKE
216
116
807
607
HUSKY
341
JACKFISH CREEK
117
516
MOUTH
342
115
809
609
UNION
BURNT LAKE
218
118
361
MAY LAKE
219
119
362
CREEK
MARIE LAKE
220
120
363
MARIE
ETHEL LAKE
221
121
802
602
ESSO
364
1211
521
MOUTH
603
703
365
122
PRIMROSE LAKE
231
131
138
MEDLEY RIVER AT MOUTH
132
382
381
MARTINEAU RIVER
133
NORCEN GULF
601
801
COLD LAKE
233
88
COLD RIVER
134
606
CHEVRON
806
89
333
130
525
MOUTH
125
332
CREEK
CHARLOTTE LAKE
224
124
331
MURIEL
MURIEL LAKE
223
123
804
604
PETRO-CAN
353
529
MOUTH
129
352
CREEK
SUNCOR
611
811
ANGLING LAKE
228
128
351
REITA
227
REITA LAKE
127
LEGEND
LAKE OR RESERVOIR
NATURAL INFLOW
JUNCTION
FLOW LINK
MAJOR WITHDRAWAL

BEAVER RIVER - COLD LAKE

REGIONAL WATER RESOURCES STUDY

WATER BALANCE MODEL SCHEMATIC

FIGURE 2.1

TABLE 2.1

SIMULATED ELEMENTS OF PHYSICAL SYSTEM

LAKES

Node No.	204	CARIBOU
	206	WOLF
	210	MOOSE
	212	MANATOKAN
	216	TUCKER
	218	BURNT
	219	MAY
	220	MARIE
	221	ETHEL
	223	MURIEL
	224	CHARLOTTE
	227	REITA
	228	ANGLING
	231	PRIMROSE
	233	COLD

RIVER REACHES

Link No.	301	SAND below CARIBOU
	302	SAND above WOLF
	304	SAND above TRUMAN
	305	SAND below TRUMAN
	306	SAND at MOUTH
	303	WOLF below WOLF LAKE
	391	BEAVER below GOODRIDGE
	392	BEAVER above MANATOKAN
	393	BEAVER above JACKFISH
	394	BEAVER above MARIE
	395	BEAVER above MURIEL
	396	BEAVER above REITA
	99	BEAVER above SASKATCHEWAN BORDER
	311	MOOSELAKE RIVER below MOOSE LAKE
	312	MOOSELAKE RIVER at MOUTH
	341	JACKFISH below TUCKER LAKE
	342	JACKFISH at MOUTH
	361	MARIE below BURNT LAKE
	362	MARIE below MAY LAKE
	363	MARIE below MARIE LAKE
	364	MARIE below ETHEL LAKE
	365	MARIE at MOUTH
	331	MURIEL below MURIEL LAKE
	332	MURIEL below CHARLOTTE LAKE
	333	MURIEL at MOUTH
	351	REITA below REITA LAKE
	352	REITA below ANGLING LAKE
	353	REITA at MOUTH
	382	MEDLEY at MOUTH
	361	MARTINEAU below PRIMROSE LAKE
	88	COLD RIVER below COLD LAKE

The analysis combined domestic, municipal withdrawals and irrigation demand at the nodes since the magnitude of this use is relatively small. Water is removed from the modelled system in accordance with a minor withdrawal data file. The insitu use of water is modelled by providing desired lake levels and preferred streamflow to the model. These states are achieved providing there is adequate water supply after uses with higher priority have been met. Major withdrawals (usually industrial and municipal) are modelled as separate components in the model network. The magnitude of these withdrawals are varied to suit different scenarios of economic development or maximum capacity of the supply system to provide water. Since a great proportion of the industrial withdrawal is not returned to the river system, the model removes the consumed water from the network.

There are several processes working in the model;

1. natural runoff
2. conservation of flow at nodes
3. lake or reservoir routing of flows
4. lake or reservoir evaporation and precipitation
5. consumption of water

The first process, natural runoff, is simulated by providing a data file of daily flows for all inflow points for the simulation period. These daily flows can be comtined in the model, to give weekly flows, monthly flows or flow over any interval, the length of which is an integral number of days not exceeding one year.

Conservation of flow is assured in the model by making all flow from a node equal to the flow into the node. Minor withdrawals while they are not shown as a link in the network, are extracted from the flow at a node. The model does not permit storage of water in the channel reaches. Storage can occur in lakes or controlled reservoirs and the change in storage equals the difference between lake outflow and inflow and net evaporation.

The routing of flows through lakes is achieved by ensuring the magnitude of the outflow from the lake outlet is in accordance with stage-storage and stage-discharge relationships. This process is iterative within the model and a numerical integration technique is used to ensure the accuracy of the final outflow.

Lake evaporation and precipitation is calculated from an input file of net evaporation (evaporation minus precipitation) for each day in the simulation period. The net evaporation is subtracted from the lake level at the end of each month or week simulated. This method, although simplistic, is sufficiently accurate for the purposes of the study.

The process of consumption of water at industrial withdrawals and minor withdrawals at nodes is achieved by adding an arc from each of these nodes to a hypothetical node called the system balance node. When flow moves along the arcs to the system balance node, it is effectively removed from the system or consumed. Water can however be withdrawn from the system and a portion returned via an arc called a return flow channel.

2.3 SYSTEM OPERATING PROCEDURES

The water balance model incorporates an algorithm for allocation of water between contending uses. Industrial use of water is often not compatible with the recreational use of the same water. A management policy must therefore be formulated to set priorities between the various water uses. These overall priorities are input to the model as a set of penalty points; with the use having the highest priority assigned the highest penalty.

Each water use in the model has a set of flow ranges or levels. The preferred or desired state is called ideal while ranges below the ideal are called relaxation ranges. Ranges above the ideal are overflow or spill levels. For example, an industrial withdrawal has an ideal demand of 1.0 cubic metres per second (m^3/s) with relaxation ranges of 90 to 100%, 75 to 90% and 0 to 75% of the ideal flow. No overflow range is permitted on industrial withdrawals. Lakes or reservoirs, conversely, have ideal levels, usually set for recreation, regulation or flood prevention purposes and relaxation levels below the ideal. Each range within a water use can be assigned a unique penalty such that there are priorities between various levels of satisfaction of the ideal state in each water use. For instance, the maintenance of an ideal lake level could have priority over an industrial withdrawal until the withdrawal is only receiving 90% of its ideal flow, then the lake could be drawn down to its first relaxation level before any further reduction in the water supply to the industrial withdrawal.

The assignment of penalties to all ranges for each water use within the input data to the model establishes the operating procedures for the modelled system. The allocation algorithm minimizes the sum of penalties for all water uses. The penalty in each water use is the product of the deviation from the ideal and the penalty in each relaxation range between the achieved and ideal flow. In the above described manner, the model can, with a multi-level set of use priorities, simulate almost any management policy.

2.4 INPUT DATA AND OUTPUT

The water balance model requires a comprehensive data base organized in a logical manner. The input data is divided into five blocks:

1. Simulation Control
2. Physical System
3. Penalty System
4. Water Supply
5. Water Demands

Simulation Control Data consists of;

(a) model run description - a complete description of the simulation run. These data are standard output on the first printout page and serve as a record of the special features of the simulation.

(b) calculation information - defines the duration of the simulation, the length of the simulation time intervals, and, if there is an apportionment agreement, the length of the apportionment period.

The description of the Physical System which is to be modelled is included in the input data by assigning an arbitrary but unique, integer number to each node and flow link on the model schematic. Each model component is either a node or a flow to link, i.e.

MODEL COMPONENT	REPRESENTATION IN THE FLOW NETWORK
Reservoir or Lake	Node
Natural, Apportionment and Diversion Channel	Flow Link
Junction	Node
Industrial Withdrawal	Node

The connectivity of the network is defined in the input data.

The physical characteristics of each component in the model is required. Reservoir or lake components need storage/elevation and meteorological data for calculation of net evaporation. The maximum capacity of channels; and,for the apportionment channels, data specific to the apportionment agreement are required. Irrigation components are defined in terms of irrigated area, and return flow channels. The return flow channel(s) associated with a major withdrawal are required. Outlet structures, although not components themselves, modify the maximum capacity of release channels depending on the water surface elevation of the reservoir or lake where the structure is located. The nature and appropriate constants for the control sturcture are provided in the data.

The Penalty System for the model is described in the input data by:

a) the number of ranges, relaxation and overflow, and associated penalty for each model component

b) the flow value or elevation for the top of each range for all components

Although the penalties remain fixed during the full simulation period, the flow ranges or levels associated with these penalties can change throughout the calendar year. For instance, the ideal level for a stream flow may be 1.0 m^3/s in May, 1.2 m^3/s in June, 0.9 m^3/s for the first two weeks in August, etc.

Water Supply and Demand data are defined for each time interval within the simulation period. The data consists of inflow, demands by withdrawal components, and net evaporation. When this data is cyclical, such as municipal and withdrawal demands, only one complete cycle of data is required. In addition to the above, the initial elevation of all reservoirs and lakes in the modelled system must be provided in the input data.

The output from the water balance model is:

a) channel flow in m^3/s

b) reservoir and lake elevations in metres

c) consumption of water at industrial withdrawals in m^3/s

d) return flows in m^3/s

An output value is produced for each component, with the exception of junctions, in the modelled system for each time interval simulated. The entire output is directed to on-line storage for future analysis. The user may select components for immediate printout. Figure 2.4 is a copy of one page of the standard printout.

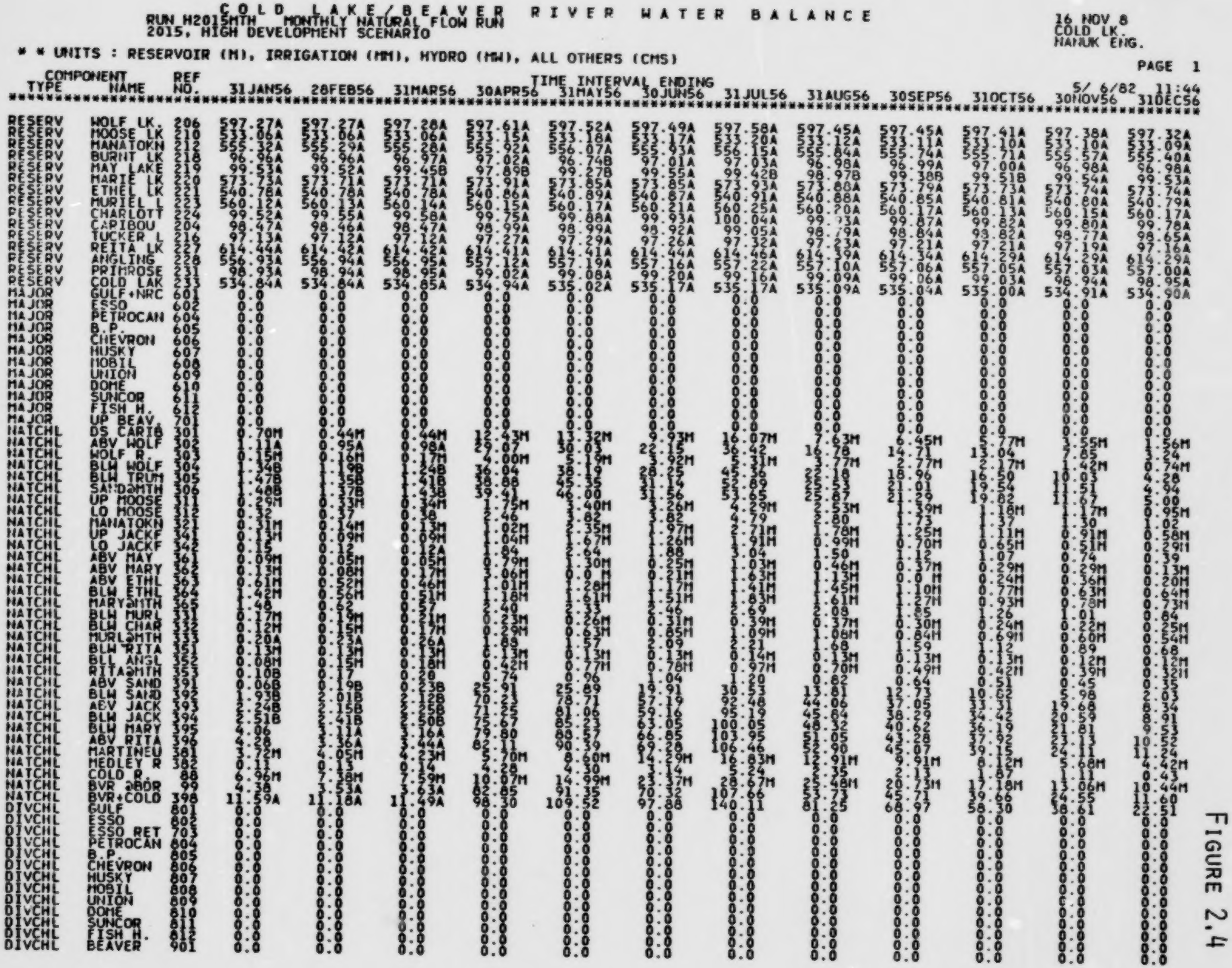
The channel flow and reservoir elevation are, respectively, the average flow during, and the final level at the end of, the simulation time interval. The output for a withdrawal component represents flow from the system i.e. consumption at the withdrawal node. Certain flows which occur in the modelled system are not output since they are unchanged from the input values. They include inflows, minor withdrawals, evaporation and precipitation from reservoirs. An echo print of the input data is also produced as part of the standard output.

2.5 MODEL CAPABILITY AND ACCURACY

The water balance model is capable of simulating the flow of water in a variety of water resource systems, from simple to large and complex. The Marie Creek sub-basin for instance, can be modelled separately or within the overall system shown in the model schematic (Figure 2.1). The model is very flexible and allows quick and easy adjustment of the level of detail and the number of physical system components represented. This is achieved by deciding which components of the physical system will be included in the model and drawing a schematic of the system to be modelled. The input data for the computer giving new node and link numbers is easily changed to suit the schematic.

Any set of time intervals, each different in length from each other providing a time interval consists of an integer number of days can be used to represent a calendar year. Presently, the maximum number of time intervals in a year is 60. The model can simulate any number of years in a simulation period.

BEAVER RIVER-COLD LAKE
WATER BALANCE MODEL
STANDARD PRINTOUT



```
                         C O L D   L A K E / B E A V E R   R I V E R   W A T E R   B A L A N C E                  16 NOV 8
              RUN H2015MTH   MONTHLY NATURAL FLOW RUN                                                           COLD LK.
              2015, HIGH DEVELOPMENT SCENARIO                                                                   HANUK ENG.
 * * UNITS : RESERVOIR (M), IRRIGATION (MM), HYDRO (MW), ALL OTHERS (CMS)
                                                                                                                 PAGE  1
   COMPONENT         REF                                  TIME INTERVAL ENDING                              5/ 6/82  11:44
  TYPE      NAME     NO.   31JAN56  28FEB56  31MAR56  30APR56  31MAY56  30JUN56  31JUL56  31AUG56  30SEP56  31OCT56  30NOV56  31DEC56
*****************************************************************************************************************************************

RESERV    WOLF LK.   206   597.27A  597.27A  597.28A  597.61A  597.52A  597.49A  597.58A  597.45A  597.45A  597.41A  597.38A  597.32A
RESERV    MOOSE LK   210   533.06A  533.06A  533.06A  533.15A  533.18A  533.17A  533.20A  533.12A  533.11A  533.10A  533.10A  533.09A
RESERV    MANATOKN   212   555.32A  555.29A  555.28A  555.92A  556.07A  555.93A  556.15A  555.84A  555.74A  555.71A  555.57A  555.40A
RESERV    BURNT LK   218    96.96A   96.96A   96.97A   97.02A   96.74B   97.01A   97.03A   96.98A   96.99A   97.00A   96.98A   96.98A
RESERV    MAY LAKE   219    99.53A   99.52A   99.45B   97.89B   99.27B   99.55A   99.42B   98.97B   99.38B   99.51B   99.54A   99.53A
RESERV    MARIE LK   220   573.73A  573.71A  573.71A  573.91A  573.85A  573.85A  573.93A  573.88A  573.79A  573.73A  573.74A  573.74A
RESERV    ETHEL LK   221   540.78A  540.78A  540.78A  540.86A  540.89A  540.87A  540.91A  540.88A  540.85A  540.81A  540.80A  540.79A
RESERV    MURIEL L   223   560.12A  560.13A  560.14A  560.15A  560.17A  560.21A  560.25A  560.20A  560.17A  560.13A  560.15A  560.17A
RESERV    CHARLOTT   224    99.52A   99.55A   99.58A   99.75A   99.88A   99.93A  100.04A   99.93A   99.87A   99.82A   99.80A   99.78A
RESERV    CAPIBOU    204    98.47A   98.46A   98.47A   98.99A   98.99A   98.92A   99.05A   98.79A   98.84A   98.82A   98.77A   98.65A
RESERV    TUCKER L   216    97.13A   97.12A   97.12A   97.27A   97.29A   97.26A   97.32A   97.23A   97.21A   97.21A   97.19A   97.16A
RESERV    REITA LK   227   614.44A  614.42A  614.42A  614.41A  614.41A  614.44A  614.46A  614.39A  614.34A  614.29A  614.29A  614.29A
RESERV    ANGLING    228   556.93A  556.94A  556.95A  557.12A  557.19A  557.16A  557.22A  557.10A  557.06A  557.05A  557.03A  557.00A
RESERV    PRIMROSE   231    98.93A   98.94A   98.95A   99.02A   99.08A   99.20A   99.16A   99.09A   99.06A   99.03A   98.94A   98.95A
RESERV    COLD LAK   233   534.84A  534.84A  534.85A  534.94A  535.02A  535.17A  535.17A  535.09A  535.04A  535.00A  534.91A  534.90A
MAJOR     GULF+NRC   601     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
MAJOR     ESSO       602     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
MAJOR     PETROCAN   604     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
MAJOR     B.P.       605     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
MAJOR     CHEVRON    606     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
MAJOR     HUSKY      607     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
MAJOR     MOBIL      608     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
MAJOR     UNION      609     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
MAJOR     DOME       610     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
MAJOR     SUNCOR     611     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
MAJOR     FISH H.    612     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
MAJOR     UP BEAV.   701     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
NATCHL    DS CARIB   301     0.70M    0.44M    0.44M   12.43M   13.32M    9.93M   16.07M    7.63M    6.45M    5.77M    3.55M    1.56M
NATCHL    ABV WOLF   302     1.11A    0.95A    0.98A   29.07    30.03    22.15    36.42    16.78    14.71    13.04     7.85     3.24
NATCHL    WOLF R.    303     0.15M    0.16M    0.17M    4.00M    5.19M    3.92M    5.31M    3.77M    2.77M    2.17M    1.42M    0.74M
NATCHL    BLW WOLF   304     1.34B    1.19B    1.24B   36.04    38.19    28.25    45.36    22.18    18.96    16.50    10.03     4.28
NATCHL    BLW TRUM   305     1.47B    1.35B    1.41B   38.88    45.35    31.14    52.89    25.53    21.01    19.54    11.51     4.94
NATCHL    SAND@MTH   306     1.48B    1.37B    1.43B   39.41    46.00    31.56    53.65    25.87    21.29    19.82    11.67     5.00
NATCHL    UP MOOSE   311     0.29M    0.33M    0.34M    1.75M    3.40M    3.26M    4.29M    2.53M    1.39M    1.18M    1.17M    0.95M
NATCHL    LO MOOSE   312     0.32     0.37     0.38     2.46     3.82     3.82     4.79     2.80     1.73     1.37     1.30     1.02
NATCHL    MANATOKN   321     0.31M    0.14M    0.13M    1.02M    2.35M    1.97M    2.71M    1.78M    1.25M    1.11M    0.91M    0.58M
NATCHL    UP JACKF   341     0.13M    0.09M    0.09M    1.04M    1.67M    1.26M    1.91M    0.99M    0.70M    0.65M    0.51M    0.29M
NATCHL    LO JACKF   342     0.15     0.12     0.12A    1.84     2.64     1.88     3.04     1.50     1.12     1.07     0.74     0.39
NATCHL    ABV MAY    361     0.09M    0.05M    0.05M    0.79M    1.30M    0.25M    1.03M    0.46M    0.37M    0.29M    0.29M    0.13M
NATCHL    ABV MARY   362     0.13M    0.08M    0.17M    3.06M    0.0 M    0.21M    1.63M    1.13M    0.0 M    0.24M    0.36M    0.20M
NATCHL    ABV ETHL   363     0.61M    0.52M    0.46M    1.01M    1.28M    1.17M    1.41M    1.45M    1.10M    0.77M    0.63M    0.64M
NATCHL    BLW ETHL   364     1.42M    0.56M    0.51M    1.18M    1.61M    1.51M    1.83M    1.61M    1.27M    0.93M    0.78M    0.73M
NATCHL    MARY@MTH   365     1.48     0.62     0.57     2.40     2.33     2.46     2.69     2.08     1.85     1.26     1.01     0.84
NATCHL    BLW MURL   331     0.17M    0.19M    0.21M    0.23M    0.26M    0.31M    0.39M    0.37M    0.30M    0.24M    0.22M    0.25M
NATCHL    BLW CHAR   332     0.12M    0.15M    0.17M    0.29M    0.63M    0.85M    1.09M    1.08M    0.84M    0.69M    0.60M    0.54M
NATCHL    MURL@MTH   333     0.20A    0.23A    0.26A    1.88     1.57     2.09     2.21     1.68     1.59     1.12     0.89     0.68
NATCHL    BLW RITA   351     0.13M    0.13M    0.13M    0.13M    0.13M    0.13M    0.14M    0.13M    0.13M    0.13M    0.12M    0.12M
NATCHL    BLL ANGL   352     0.08M    0.15M    0.18M    0.42M    0.77M    0.78M    0.97M    0.70M    0.49M    0.42M    0.39M    0.32M
NATCHL    RITA@MTH   353     0.10B    0.17     0.20     0.74     0.96     1.04     1.20     0.82     0.64     0.51     0.45     0.35
NATCHL    ABV SAND   391     0.06B    0.19B    0.23B   25.91    25.89    19.91    30.53    13.81    12.73    10.62     5.98     2.03
NATCHL    BLW SAND   392     1.93B    2.01B    2.12B   70.23    78.71    57.19    92.48    44.06    37.05    33.31    19.68     8.34
NATCHL    ABV JACK   393     2.24B    2.15B    2.25B   71.25    81.06    59.16    95.19    45.84    38.29    34.42    20.59     8.91
NATCHL    BLW JACK   394     2.51B    2.41B    2.50B   75.67    85.23    63.05   100.05    48.32    40.62    36.19    21.81     9.53
NATCHL    BLW MARY   395     4.06     3.11A    3.16A   79.80    88.57    66.85   103.95    51.05    43.28    37.92    23.13    10.52
NATCHL    ABV RITA   396     4.28     3.36A    3.44A   82.11    90.39    69.28   106.46    52.90    45.07    39.15    24.11    11.24
NATCHL    MARTINEU   381     3.72M    4.05M    4.23M    5.70M    8.60M   14.29M   16.83M   12.91M    9.91M    8.12M    5.68M    4.42M
NATCHL    MEDLEY R   382     0.11     0.13     0.14     4.28     4.30     3.14     5.24     2.35     2.13     1.87     1.11     0.43
NATCHL    COLD R.     88     6.96M    7.38M    7.59M   10.07M   14.99M   23.37M   28.67M   25.48M   20.73M   17.18M   13.06M   10.44M
NATCHL    BVR @BDR    99     4.38     3.53A    3.63A   82.85    91.35    70.32   107.66    53.73    45.71    39.66    24.55    11.60
NATCHL    BVR+COLD   398    11.59A   11.18A   11.49A   98.30   109.52    97.88   140.11    81.25    68.97    58.30    38.61    22.51
DIVCHL    GULF       801     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    ESSO       802     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    ESSO RET   703     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    PETROCAN   804     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    B.P.       805     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    CHEVRON    806     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    HUSKY      807     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    MOBIL      808     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    UNION      809     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    DOME       810     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    SUNCOR     811     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    FISH H.    812     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVCHL    BEAVER     901     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
```

FIGURE 2.4

The model can include a large number of system components to a maximum of:

1. nodes = 100
2. flow links = 150
3. outlet structures = 30
4. reservoirs = 30
5. meteorlogical stations = 20
6. irrigation components = 25
7. hydropower plants = 20
8. natural channels = 75
9. diversion channels = 40
10. apportionment channels = 5
11. major withdrawals = 10

The water balance model is a simulation model and no optimization of the operating rules or physical configuration is performed. The user prescribes a physical system and defines the operating system and the performance of the system must be analyzed and judged by the user. The model does not simulate the hydrodynamic nature, i.e., velocity, depth, channel storage, of river flows. There is no routing of river flows and water entering the system at any point within one time interval can flow to any other point in the network (when feasible) within the same time interval. Therefore, the time interval should be greater than the time of travel from the most upstream point to the most downstream point in the modelled basin.

The accuracy of the simulation performed by the water balance model is primarily dependent on the hydrologic data input. Two factors may cause variance bewteen modelled results and recorded data or results from other hydrologic simulation models. The water balance model does not incorporate lag into streamflows; although on a weekly or monthly basis for simulation, this factor is judged to have minimal effect on accuracy. The second factor is the method of routing water through a lake with a natural or similar outlet. The simulated outflows are dependent on the method used and the simulation time interval. For the above reasons, input data and modelling methodology, the results from the simulation model are not necessarily meaningful for a particular time interval but the long term, multi-interval and statistical results are representative of the recorded events which produced the hydrologic input data.

2.6 TECHNOLOGY TRANSFER

One of the tasks in the water balance model component was the transfer to Planning Division, Alberta Environment of the ability to prepare input data and run the computer programs that comprise the modelling system. The model has been set up on the Alberta Government Services facilities in the Terrace Building and although it is a batch program, can be run by using the ROSCOE time sharing facility telecommunication lines and remote terminals.

Documentation on the water balance model is maintained by Systems and Computing Branch although their version varies in minor ways from the model used in this study. The basic difference lies in the output summary program and preparation of data on disk files by the model simulation program. The System and Computing version will however use the same input data and provide identical results to the model used by Nanuk Engineering. During the course of the study, Planning Division staff have been familiarized with the model, in particular the penalty point system which sets the method of operation of the model. The technology transfer to Alberta Environment has therefore been accomplished by establishing the computer programs on government facilities, providing documentation and staff familiarization and instruction.

SECTION 3

TESTING OF MODEL
&
INITIAL BASIN ANALYSIS

3. TESTING OF MODEL & INITIAL BASIN ANALYSIS

3.1 NATURAL FLOW SIMULATION

Calibration and verification of the water balance model was performed on a simulation of the natural flow in the Beaver and Cold River basins. Natural flow, in this context, is defined as the flow which would currently occur in the basins, with existing outlet structures and no withdrawals, industrial or municipal. Since the inflows to the water balance model for the simulation period 1956 to 1980 were provided by Northwest Hydraulic Consultants (NHC), and a routing simulation by NHC provided natural flows in most of the river reaches in the water balance model, these inflows and results were used to calibrate and verify the model. Ecos Engineering provided inflow hydrology for 1981. Recorded flows of the Beaver River at the Cold Lake Indian Reserve were also compared to the modelled flows at the same point.

The basin was simulated using the network displayed in Figure 2.1. The major withdrawals were not active. Inflows were as provided by Northwest Hydraulics and Ecos Engineering. All outlet structures were assumed to discharge water in a manner similar to the existing outlets on the modelled lakes.

The validity of the simulation model can be measured by comparison of the simulated flows and lake levels to the recorded values providing the water withdrawals and outlet control are the same in both situations. Since all the outlet structures in the region are uncontrolled, and the recent level of withdrawals is minimal, the comparison between recorded and simulated values is meaningful.

Recorded values are not available for most of the physical components simulated. Therefore several components with recorded data were selected as being representative of the quality of the simulation. The following comparisons of recorded to simulated values have been made;

Monthly Flows:	Beaver River @ Cold Lake Reserve (Plate 3.1.1) Sand River @ Truman (Plate 3.1.2)
Monthly Lake Levels:	Cold Lake, 1956 to 1981 (Plate 3.1.3)
Weekly Lake Levels:	Wolf Lake, 1980 to 1981 (Plate 3.1.4)
Weekly Flows:	Wolf River, 1979 to 1981 (Plate 3.1.5)

Tables 3.1.1 and 3.1.2 display the annual flows, recorded and simulated, of the Beaver River at Cold Lake Reserve and the Sand River at Truman.

3.2 SIMULATION OF 2015 WATER DEMAND SCENARIO

The purpose of this simulation was the evaluation of the capability of, and effect on, the basin of satisfying the highest level of water demand projected for the year 2015 by development of several heavy oil extraction plants.

3.2.1 BASIS OF SIMULATION

The basin was simulated in the configuration shown on Figure 2.1. The withdrawals required by the heavy oil extraction plants were in accordance with the demands initially reported by MacLaren Plansearch in "Withdrawal Water Demands". The Murphy Oil development was assumed to have withdrawn water from the North Saskatchewan River. In addition to these requirements, there were municipal and irrigation withdrawals from Cold Lake, Moose Lake and the Beaver River above Goodridge. The magnitude of these withdrawals are provided in Appendix B. The heavy oil plants located on lakes were permitted to withdraw water down to the sill of the outlet structure.

The outlet structures, on the lakes, were modelled as they currently exist in the basin. Since all the existing outlets are uncontrolled, the outflow from the lakes corresponds to the stage/

TABLE 3.1.1

COMPARISON OF RECORDED & SIMULATED NATURAL FLOWS BEAVER RIVER AT COLD LAKE RESERVE

YEAR	SIMULATED FLOW (dam^3 x10^3)	RECORDED FLOW (dam^3 x10^3)	RESIDUAL*/ RECORDED x 100%
1956	1,406	1,360	+ 3.4
1957	474	464	+ 2.2
1958	566	555	+ 2.0
1959	501	518	- 3.3
1960	1,418	1,370	+ 3.5
1961	695	675	+ 3.0
1962	1,983	1,920	+ 3.3
1963	922	884	+ 4.3
1964	341	354	- 3.7
1965	1,008	989	+ 1.9
1966	594	596	- 0.3
1967	408	423	- 3.5
1968	214	241	-12.6
1969	671	677	- 0.9
1970	1,479	1,410	+ 4.9
1971	1,499	1,400	+ 7.1
1972	502	489	+ 2.7
1973	915	881	+ 3.9
1974	1,738	1,700	+ 2.2
1975	1,117	1,050	+ 6.4
1976	662	624	+ 6.1
1977	472	479	- 1.5
1978	781	750	+ 4.1
1979	819	831	- 1.4
1980	442	457	- 3.3
1981	316	296	+ 6.7

* Residual = Simulated-Recorded

TABLE 3.1.2

COMPARISON OF RECORDED & SIMULATED NATURAL FLOWS
SAND RIVER AT TRUMAN

YEAR	SIMULATED FLOW (dam^3 x10^3)	RECORDED FLOW (dam^3 x10^3)	RESIDUAL*/ RECORDED x 100%
1956	674	NR	
1957	229	NR	
1958	274	NR	
1959	255	NR	
1960	676	NR	
1961	333	NR	
1962	946	NR	
1963	437	NR	
1964	174	NR	
1965	488	NR	
1966	293	NR	
1967	214	NR	
1968	128	NR	
1969	362	322	+12.4
1970	792	698	+13.4
1971	650	595	+ 9.2
1972	238	207	+15.0
1973	599	528	+13.4
1974	799	731	+ 9.3
1975	578	519	+11.4
1976	438	386	+13.4
1977	255	210	+21.4
1978	343	294	+16.6
1979	398	348	+14.4
1980	308	271	+13.6
1981	187	158	+18.4

NR - No record

* Residual = Simulated-Recorded

discharge relationship for the particular structures. The stage/discharge and stage/storage curves for the existing outlets are provided in Appendix B. There was no attempt made in simulation to satisfy minimum flows in the outflow channels or within the basin by reducing withdrawals to increase flows from the outlet structures. Curtailing the withdrawal at the sill elevation of the outlet structure eliminates or reduces periods of zero flow in the outflow channel.

The starting elevation for the lakes at the beginning of the simulation period was as provided by Northwest Hydraulic Consultants (Appendix B). The basin was simulated on a weekly basis from 1956 to 1981 inclusive.

3.2.2 SIMULATION RESULTS

The effects of the withdrawal of water to satisfy the greatest requirements of basin development projected for year 2015 can be measured by:

(a) comparing the reduced flows to Saskatchewan with the natural

(b) the reduction in median flows from the natural case

(c) annual shortages incurred by major withdrawals

(d) comparison of lake levels and flows with and without withdrawals

(e) reduction in median lake levels from the natural case

Table 3.2.2.1 shows that the maximum reduction in annual flow of the Beaver River at the Saskatchewan Border is 10.2% less than the simulated natural flow. The observance of the Apportionment Agreement with Saskatchewan and Manitoba can therefore be easily kept for a very high level of development in the heavy oil extraction industry.

TABLE 3.2.2.1

ANNUAL FLOWS
BEAVER RIVER AT SASKATCHEWAN BORDER

YEAR	DEVELOPED FLOWS ($dam^3 x 10^3$)	NATURAL FLOWS ($dam^3 x 10^3$)	% REDUCTION IN FLOW
1956	1453	1488	2.3
1957	469	505	7.1
1958	568	602	5.6
1959	502	534	6.0
1960	1463	1502	2.6
1961	705	738	4.5
1962	2063	2098	1.7
1963	944	977	3.4
1964	336	365	7.9
1965	1030	1068	3.6
1966	596	632	5.7
1967	406	436	8.3
1968	210	234	10.2
1969	678	714	5.0
1970	1509	1548	2.5
1971	1531	1567	2.3
1972	499	531	6.0
1973	918	955	3.9
1974	1835	1872	2.0
1975	1143	1181	3.2
1976	651	688	5.4
1977	465	496	6.3
1978	771	806	4.3
1979	815	851	4.2
1980	428	459	6.8
1981	302	330	8.5

Table 3.2.2.2 comparies the median monthly flows at eight key reaches in the basin for the natural and withdrawal simulations. Since the absolute difference between the median flows remains almost constant, the greatest relative reduction occurs in the fall and winter months when flows are low. This is particularly evident on the Wolf River, Marie and Reita Creeks.

The absolute and relative, annual shortages incurred by the major withdrawals are displayed on Table 3.2.2.3. Shortages are caused, in the model, by not permitting withdrawals in time intervals when the lake level is below the sill, or when river flows fall below the withdrawal rate.

Plates 3.2.1 and 3.2.2 compare the natural and the year 2015 high development simulations for water levels and outflows for Wolf Lake. The comparison shows that low flows are significantly reduced but the pattern of flows remains similar. The lake levels are also reduced causing substantially lower minimum levels in 1960, 1964, 1967, 1968 and 1980.

The comparison between natural and developed lake levels provided in Table 3.2.2.4 shows the smaller lakes such as Angling and Ethel are significantly affected, whereas the larger lakes like Wolf and Cold are affected only slightly by the withdrawals projected for the 2015 high development scenario. Angling Lake's median annual elevation is reduced by 0.1 metre and Ethel by 80 centimetres. Cold Lake goes down by 10 centimetres and Wolf Lake shows a drop of 30 centimetres.

3.3 WATER QUALITY FLOWS

The assessment of the effect of increased water withdrawals on the water quality of the region and the initial set-up of the water quality model required input data from the water balance model. The computer simulation described in the previous section 3.2 'Simulation of 2015 High Water Demand Scenario' was used to provide the 1 in 10 year, weekly low flows of the Beaver River at the Saskatchewan Border and the concurrent

TABLE 3.2.2.2

% REDUCTION IN MONTHLY MEDIAN STREAMFLOWS: NATURAL/DEVELOPED

YEAR 2015 HIGH DEVELOPMENT SCENARIO

(m^3/s)

MONTH	BEAVER RIVER @ COLD LAKE RESV	SAND RIVER @ TRUMAN	WOLF RIVER @ MOUTH	MARIE CREEK @ MOUTH	COLD RIVER @ COLD LAKE	REITA CREEK @ MOUTH	MURIEL CREEK @ MOUTH	JACKFISH CREEK @ MOUTH
JAN.	12	17	66	59	4	88	7	19
FEB.	19	19	83	65	3	86	6	32
MAR.	16	19	85	67	3	77	6	31
APR.	3	7	49	26	4	36	3	6
MAY	2	3	24	28	3	40	1	3
JUN.	4	4	14	23	2	32	5	5
JUL.	4	4	22	25	2	64	4	6
AUG.	6	5	30	27	2	44	2	12
SEP.	4	4	43	11	2	14	4	15
OCT.	5	6	39	33	2	44	4	20
NOV.	9	8	38	33	2	59	4	13
DEC.	13	12	64	73	3	85	5	21

TABLE 3.2.2.3

ANNUAL SHORTAGES AT MAJOR WITHDRAWALS

YEAR 2015 HIGH DEVELOPMENT SCENARIO

NODE	WITHDRAWAL NAME	SOURCE	SHORTAGE (dam^3)	% OF DEMAND
601	Norcen/Gulf	Cold Lake	0	0
602	Esso	Ethel Lake	1430	21.3
604	Petro-Canada	Muriel Lake	612	51.5
605	B.P. Canada	Wolf Lake	756	6.9
606	Chevron Standard	Beaver River	2	1.7
607	Husky Oil	Tucker Lake	242	19.8
608	Mobil Oil	Manatokan Lake	67	3.1
609	Union Texas	Beaver River	1	.2
610	Dome	Sand River	42	.6
611	Suncor	Angling Lake	34	.1

TABLE 3.2.2.4

ANNUAL MEDIAN LAKE LEVELS: NATURAL/DEVELOPED

YEAR 2015 HIGH DEVELOPMENT SCENARIO

LAKE		MEDIAN ANNUAL ELEVATION metres		NET CHANGE metres
NODE	NAME	NATURAL	DEVELOPED	
206	Wolf	597.34	597.31	-.03
212	Manatokan	555.35	555.32	-.03
233	Cold	534.98	534.97	-.01
221	Ethel	540.75	540.67	-.08
216	Tucker	553.75	553.74	-.01
223	Muriel	560.01	559.99	-.02
228	Angling	556.93	556.83	-.10

flows in other reaches of interest. These flows presented in Table 3.3.1 were forwarded to MacLaren Plansearch for the water quality assessment and modelling component.

The base case for water quality assessment was the natural flow simulation. Flow data from the water balance model was transmitted for use in the water quality model. The data was in the form of weekly low flows for the winter and summer periods with return periods of 1 in 5 and 1 in 10 year. The simulated flow record of the Beaver River at the Saskatchewan Border was analyzed to give the 1 in 5 and 1 in 10 year winter and summer low flows. The flows for the corresponding period in the other reaches of interest were then listed to give a compatible set of low flows for the region. These flow values are presented in Table 3.3.2.

TABLE 3.3.1

FLOWS FOR SIMULATION WEEK ENDING 7 OCT 67
YEAR 2015 HIGH DEVELOPMENT SCENARIO

STUDY POINT NO.	DESCRIPTION	FLOW VALUE m^3/s	RETURN PERIOD YEARS
1.	CARIBOU LAKE OUTLET	.52	9
2.	SAND RIVER @ WOLF RIVER	1.01	-
3.	WOLF LAKE OUTLET	.04	4
4.	SAND RIVER @ TRUMAN	1.05	10
5.	PUNK CREEK @ SAND RIVER	.19	3
6.	BEAVER RIVER @ GOODRIDGE	.37	4
7.	BEAVER RIVER @ MOOSE RIVER	.47	5
8.	MOOSE RIVER @ MOUTH	.04	2.5
9.	BEAVER RIVER @ SAND RIVER	.51	5
10.	SAND RIVER @ MOUTH	1.26	10
11.	MANATOKAN LAKE OUTLET	0.0	-
12.	MOOSE LAKE OUTLET	0.0	-
13.	CHARLOTTE LAKE OUTLET	.04	4
14.	BEAVER RIVER @ JACKFISH CREEK	1.91	8
15.	JACKFISH CREEK @ MOUTH	.03	3
16.	TUCKER LAKE OUTLET	0.0	-
17.	BEAVER RIVER @ MARIE CREEK	2.01	8
18.	MARIE CREEK @ MOUTH	.07	2.5
19.	ETHEL LAKE OUTLET	0.0	-
20.	BEAVER RIVER @ MURIEL CREEK	2.11	8
21.	MURIEL CREEK @ MOUTH	.13	2.5
22.	BEAVER RIVER @ REITA CREEK	2.24	8
23.	REITA CREEK @ MOUTH	0.02	2
24.	ANGLING LAKE OUTLET	0.0	-
25.	BEAVER @ BORDER	2.52	9

TABLE 3.3.2

WEEKLY LOW FLOWS
FROM
NATURAL SIMULATION

STUDY POINT NO.		WINTER		SUMMER	
		1 in 10* Year (m^3/s)	1 in 5* Year (m^3/s)	1 in 10* Year (m^3/s)	1 in 5* Year (m^3/s)
1.	CARIBOU LAKE OUTLET	0.20	0.18	0.38	0.51
4.	SAND RIVER AT TRUMAN	0.48	0.37	1.06	1.43
6.	BEAVER RIVER AT GOODRIDGE	0.0	0.0	0.16	0.24
7.	BEAVER RIVER AT MOOSELAKE RIVER	0.04	0.02	0.23	0.30
8.	MOOSELAKE RIVER AT MOUTH	0.01	0.36	0.22	0.0
9.	BEAVER RIVER AT SAND RIVER	0.05	0.38	0.45	0.30
10.	SAND RIVER AT MOUTH	0.56	0.41	1.20	2.69
11.	MANATOKAN LAKE OUTLET	0.09	0.11	0.11	0.0
12.	MOOSELAKE OUTLET	0.0	0.35	0.18	0.0
13.	CHARLOTTE LAKE OUTLET	0.11	0.12	0.12	0.0
14.	BEAVER RIVER AT JACKFISH CREEK	0.75	0.94	1.90	3.42
15.	JACKFISH CREEK AT MOUTH	0.05	0.07	0.05	0.0
16.	TUCKER LAKE OUTLET	0.04	0.06	0.03	0.0
17.	BEAVER RIVER AT MARIE CREEK	0.84	1.03	2.04	3.12
18.	MARIE CREEK AT MOUTH	0.07	0.39	0.33	0.06
19.	ETHEL LAKE OUTLET	0.04	0.37	0.27	0.06
20.	BEAVER RIVER AT MURIEL CREEK	0.92	1.42	2.40	3.19
21.	MURIEL CREEK AT MOUTH	0.14	0.15	0.21	0.0
22.	BEAVER RIVER AT REITA CREEK	1.06	1.57	2.61	3.19
23.	REITA CREEK AT MOUTH	0.13	0.14	0.10	0.00
24.	ANGLING LAKE OUTLET	0.12	0.13	0.08	0.0
25.	BEAVER AT BORDER	1.31	1.79	3.00	3.20

WINTER - OCTOBER to MARCH incl.

SUMMER - APRIL to SEPTEMBER incl.

* return period for Beaver @ Border only

SECTION 4

SUB-BASIN ANALYSES

4. SUB-BASIN ANALYSES

4.1 GENERAL

An obvious source of water for future development of oil-sands recovery plants and the associated increased population and industries are the lakes within Sub-Area A. Lakes are often a very desirable source of water supply. Withdrawal can be made at a constant rate without concern for inflow/outflow rates. The intake structure is inexpensive and virtually assured of submergence even in low flow conditions. The lakes within the region were therefore analyzed to determine the maximum withdrawal consistent with satisfying or exceeding lake level and streamflow criteria.

The streamflow and lake level criteria were determined for each lake by the Instream Water Users Subcommittee. The criteria reflected the needs of fish, wildlife, recreation and maintenance of lake water quality. The nature of these criteria and the values appropriate to each lake and outflow channel are presented in Section 4.2.

The lakes were simulated with two types of regulation structures on their outlet. Both types of structure dam the outlet from the lake but the methods for releasing water are different. The outflow from one structure was dependent only on the water surface elevation in the corresponding lake, whereas the rate of outflow from others could be controlled from zero to the maximum capacity of the outlet. These regulation alternatives, labelled 'unattended' and 'fully controlled', are discussed in more detail in Section 4.3.

Each sub-basin which was considered a potential source of water was analyzed independently. The sub-basin simulations used sub-models of the full model shown in Figure 2.1 such that only the lake(s) and channel(s) of interest were included. The overall effects of withdrawing the maximum available water from the lakes were analyzed in two system simulations.

4.2 OPERATING CRITERIA

For each sub-basin, criteria were derived for lake levels, stream flows and deficits in water withdrawals. A multidisciplinary committee consisting of representatives from Fish and Wildlife Division of the Department of Energy and Natural Resources, and from Parks and Recreation, a recreation consultant, environmental assessment and river basin planning staff and the water balance model representative formulated the criteria. The criteria had statistical basis, in keeping with long term, historical simulation of the Basin. The criteria are presented below;

4.2.1 LAKE LEVEL CRITERIA

Five values were established for desirable levels within each lake. The levels were given names and operating rules relative to the levels were assigned as follows:

1. 'Maximum' - the regulated lake level should not exceed
2. '10% Exceedance' - not more than 10% of the regulated lake levels should exceed
3. 'Median' - the regulated median level of the lake should not exceed
4. '90% Exceedance' - not more than 10% of the regulated lake levels should be less than this number
5. 'Minimum' - the regulated lake level should not be less than this value

The values assigned to these levels for each lake are recorded in Table 4.2.1. When more than one value suggested by the committee, the most stringent was used by the water balance model.

TABLE 4.2.1

PREFERRED/ACCEPTABLE LAKE LEVELS

(Meters A.S.L.)

	Wolf	Manatokan	Burnt	May*	Marie	Ethel	Cold	Moose	Muriel	Caribou	Angling	Reita
Maximum	598.56			605.78	574.30	541.60	535.64	533.21	560.18			
10% Exceedance	597.71	556.09	662.29	605.63	574.08	541.20	535.35	533.15	560.48	633.98	557.31	614.70
Median	597.54	555.55	662.65	605.60	573.89	541.16	535.18	533.14	560.21	633.72	557.11	614.48
90% Exceedance	597.28	555.20	662.44	605.57	573.54	540.85	534.76	532.94	559.61	633.02	556.82	613.89
Minimum	597.14	554.88	662.35	605.31	573.35	540.73	534.57	532.77	559.22	632.85	556.74	613.28

*no change from natural condition

4.2.2 STREAMFLOW CRITERIA

The withdrawal from, or regulation of a lake, affects the volume and temporal distribution of outflows from that lake. The streamflow criteria provides acceptable minimum flows for each month of the year for the outflow channel from each lake. These flows called the 'Preferred Minimum Flow' (PMF) for each month were derived from the estimated natural flows in the particular outflow channel.

The method for deriving the PMF's was based on a statistical measure of minimum flow achievement. The statistical measure was the proportion of the historical natural flows that were exceeded by the PMF in a particular month. The cumulative frequency distribution for March flows in the Wolf River, Figure 4.2.2,illustrates the statistical nature of the PMF. For March, the PMF is that flow which exceeds 40% of the natural flows,or conversely,the PMF is that flow which is exceeded by 60% of the natural flows.

The methodology used to determine PMF's in the winter was different than that used for the summer. During the winter months, October through March, the PMF was defined to be that flow which exceeded 40% of the flows in that particular month. In summer, the PMF exceeded 25% of the monthly flows. The value was determined by ranking the 26 monthly natural flows and selecting a value between the 6th and 7th smallest and 10th and 11th smallest respectively for summer and winter months. The PMF values are tabulated for each outflow channel in Table 4.2.2. The PMF's in October were calculated as an average of the September and November values since the change in the method of determining the PMF's caused an anomalous jump between September and October.

The minimum acceptable streamflow criteria were applied in a statistical manner to determine the maximum allowable withdrawal from an individual lake. The criteria were applied differently for fully controlled and unattended outlets, as follows;

CUMULATIVE FREQUENCY DISTRIBUTION

WOLF RIVER D/S WOLF LAKE

MARCH FLOWS

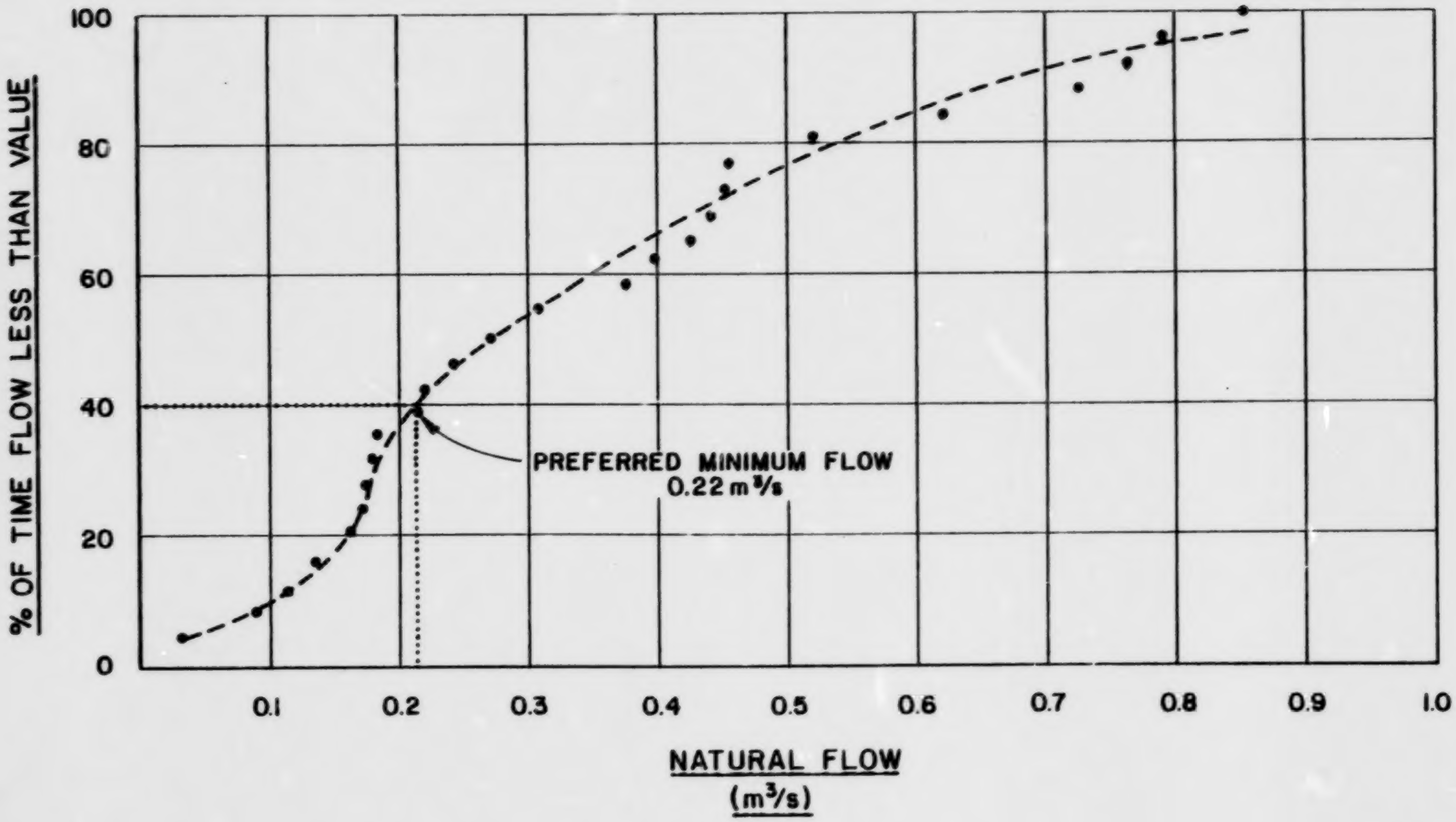


FIGURE 4.2.2

TABLE 4.2.2

MINIMUM ACCEPTABLE FLOW LEVELS

(m^3/s)

	Wolf River	Manatokan Creek	Marie Creek d/s Burnt L.	Marie Creek d/s May L.	Marie Creek d/s Marie L.	Marie Creek d/s Ethel L.	Cold River	Mooselake River	Muriel Creek d/s Muriel L.	Sand River d/s Caribou L.	Reita Creek d/s Angling L.	Reita Creek d/s Reita L.
Jan	0.30	0.13	0.08	0.12	0.30	0.33	7.07	0.24	0.0	0.71	0.06	0.0
Feb	0.24	0.12	0.05	0.07	0.30	0.33	7.43	0.22	0.0	0.58	0.07	0.0
Mar	0.22	0.11	0.05	0.07	0.28	0.31	7.57	0.21	0.0	0.47	0.06	0.0
Apr	0.68	0.19	0.15	0.17	0.12	0.17	6.71	0.21	0.0	2.49	0.05	0.0
May	1.82	0.60	0.21	0.28	0.28	0.40	11.49	0.43	0.0	3.36	0.17	0.0
Jun	0.12	0.35	0.16	0.15	0.33	0.36	16.84	0.46	0.0	2.37	0.10	0.0
Jul	0.81	0.29	0.03	0.03	0.13	0.14	17.18	0.64	0.0	1.58	0.11	0.0
Aug	0.59	0.23	0.04	0.05	0.12	0.09	17.09	0.41	0.0	1.70	0.05	0.0
Sep	0.47	0.11	0.0	0.02	0.0	0.05	14.69	0.27	0.0	1.12	0.01	0.0
Oct	0.47	0.14	0.06	0.08	0.06	0.06	11.81	0.23	0.0	1.50	0.01	0.0
Nov	0.48	0.16	0.12	0.18	0.13	0.06	8.93	0.19	0.0	1.89	0.01	0.0
Dec	0.39	0.15	0.09	0.13	0.24	0.25	6.38	0.20	0.0	1.16	0.03	0.0

- Unattended Outlet - the reduction from the natural to the regulated case, in the number of months the PMF are exceeded must not be greater than 5 percent (-5% criterion)
- Fully Controlled Outlet - the increase from the natural to the regulated case, in the number of months the PMF's are exceeded must be at least 10 percent (+10% criterion)

Examples of the application of these criteria are;

- the regulated outflows from an unattended outlet must exceed the PMF's for at least 70% of the time in the summer
- the regulated outflows from a fully controlled outlet must exceed the PMF's for at least 70% of the time in the winter

The maintenance of the absolute minimum flow was also a criterion and the increase in the absolute maximum flow was generally kept to 50 percent over the natural.

4.3 REGULATION ALTERNATIVES

Prior to initiating the sub-basin analyses, the types of regulation schemes that would be considered were standardized. The industrial withdrawal was taken directly from one lake in each sub-basin, at a constant rate but the withdrawal could be shut off or reduced to satisfy operating criteria. The outflows from the lake were regulated by two quite dissimilar types of outlet structures. Both structures dam the outflow channel but the flow through, or over, one type of structure is strictly dependent on the water surface elevation in the lake much like a natural outlet. This structure could be a fixed crest weir, culvert, or stop log spillway. It was called an unattended outlet since assurances could not be given that it would be attended when needed. For example, during a flood, one cannot be sure that crews will be able to get in to remove stop logs when needed, consequently it is appropriate and conservative to assume it is unattended. The simulation program assumed the stage/discharge curve for the unattended outlet was invariant, although stop logs, gates and valve insight provides some flexibility to increase outflows, decrease water levels, etc. when desired.

The other type of structure used in the analyses was able to control the discharge through it in response to either desired outflows or lake levels. For instance, providing the water level was above a certain value, the structure released a flow equal to the PMF value for the particular month. This type of control could be achieved by gates or valves within the dam using hydraulic or electrical means to control their position. These structures were called 'fully controlled' to differentiate them from the unattended outlets which are basically uncontrolled.

Since the flow from an unattended outlet is dependent only on the water surface elevation of the lake, the optimal stage/discharge curve must be derived to provide a maximum constant withdrawal rate while satisfying the lake level and streamflow criteria. Although direct methods of synthesizing this curve were investigated in a separate report, all the stage/discharge curves cited in this report were developed by a trial and error process. The particular curve for the outlet on each lake analyzed are displayed in Appendix C. For the fully controlled outlet the stage/discharge curve provides the maximum discharge at a given water surface elevation in the lake. The controlled outlet can release any flow up to, and including, this discharge.

4.4 WOLF RIVER

The Wolf River sub-basin was analyzed for three storage and regulation alternatives;

1. unattended structure
2. fully controlled structure
3. unattended structure and storage pond

The summaries of the simulation results from the first two analyses are presented in Table 4.4.1 and 4.4.2. The simulation incorporating a storage pond for the industrial withdrawal indicated that a pond with a 3000 dam^3 storage capacity could satisfy an annual withdrawal of 2520 dam^3 and all criteria. The simulated diversion capacity from the pond to the lake was .24 m^3/s (~3000 igpm). Filling of the pond was considered to take place during high flow periods in April through August.

The variations in water levels and release flows for the unattended and fully controlled are depicted in Plate 4.4. Comparison is made between the natural or existing lake hydrology and the regulated alternatives with the maximum potential industrial withdrawal.

Lake level fluctuations have been reduced with both types of outlet. Eighty percent of the fluctuations can be expected to be less than 0.4m for both the controlled outlet and the unattended structure. Downstream flows remain similar to the natural scenario although the fully controlled outlet tends to reduce the variability of the low flows. In summary, Wolf Lake is a good candidate for an industrial withdrawal of up to 10,700 dam^3 per annum depending on the regulation alternative chosen.

4.5 MANATOKAN CREEK

The Manatokan Creek sub-basin was analyzed for two regulation alternatives;

1. an unattended outlet with maximum potential withdrawal
2. an unattended outlet and channel improvements suggested by Ducks Unlimited for lake level stabilization and no withdrawal.

Table 4.4.1

WOLF LAKE
SIMULATION SUMMARY

Unattended Outlet
Maximum Annual Withdrawal = 6300 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	Winter	Summer
Maximum	598.01	598.56	598.06	597.74	598.06
10% Exceedance	597.51	597.71	597.70	597.58	597.73
Median	597.34	597.54	597.42	597.37	597.53
90% Exceedance	597.28	597.28	597.30	597.28	597.35
Minimum	597.14	597.14	597.19	597.23	597.19

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural			Regulated		
April	0.68	64	...		36	...	
May	1.82	71	:		44	:	
June	1.12	76	:	73	77	:	69
July	0.81	76	:		88	:	
August	0.59	73	:		85	:	
September	0.47	75	..:		85	..:	
October	0.47	71	...		76	...	
November	0.48	58	:		61	:	
December	0.39	56	:	60	52	:	58
January	0.30	58	:		57	:	
February	0.24	57	:		54	:	
March	0.22	58	..:		48	..:	

Average Annual Change in PMF Achievement -3%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	26.5	29.1

DEFICITS

Mean Annual	9.0 cu dam
Withdrawal	0.2 %
Duration, Deficit > 10%	2 weeks
Duration, Deficit > 30%	2 weeks

Table 4.4.2

WOLF LAKE
SIMULATION SUMMARY

Fully Controlled Outlet
Maximum Annual Withdrawal = 10700 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	598.01	598.56	598.01	597.71	598.01
10% Exceedance	597.51	597.71	597.71	597.71	597.71
Median	597.34	597.54	597.56	597.48	597.62
90% Exceedance	597.28	597.28	597.33	597.32	597.36
Minimum	597.14	597.14	597.20	597.22	597.20

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	0.68	64	73	72	86
May	1.82	71		85	
June	1.12	76		85	
July	0.81	76		88	
August	0.59	73		89	
September	0.47	75		93	
October	0.47	71	60	92	70
November	0.48	58		85	
December	0.39	56		54	
January	0.30	58		63	
February	0.24	57		62	
March	0.22	58		63	

Average Annual Change in PMF Achievement +12%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	26.5	27.5

DEFICITS

Mean Annual	15.0 cu dam
Withdrawal	0.1 %
Duration, Deficit > 10%	2 weeks
Duration, Deficit > 30%	2 weeks

The summaries of the simulation results from these two analyses are presented in Tables 4.5.1 and 4.5.2. A fully controlled outlet was investigated but the simulation results indicated an industrial withdrawal was not feasible if the operating criteria were to be satisfied. The variations in water levels and release flows for the above simulations are compared to the natural situation in Plate 4.5.

The Ducks Unlimited outlet achieves the objectives of lake level stabilization at the expense of summer flows in the release channel. The maximum lake level has been reduced by .6m and the overall fluctuations have been reduced from 2m to 1m. Winter release flows are improved. The unattended structure meets all the criteria but lake level fluctuations are less than, but nearly equal to, the existing natural situation. In summary, the two alternatives presented have different objectives and the choice of a regulation scheme depnds on the perceived purpose for the lake-wildfowl propogation or industrial water supply.

4.6 MARIE CREEK

The Marie Creek sub-basin contains four major lakes; Burnt, May, Marie and Ethel. After consultation with the Instream Water Users Subcommittee, May Lake was not considered for withdrawal of water for industrial purposes. The remaining three lakes were analyzed for the maximum withdrawal from each in turn, using unattended and fully controlled outlets. On Ethel Lake, a fully controlled outlet could not satisfy the streamflow criteria. The existing, unattended structure on Ethel Lake provides regulation and permits an industrial withdrawal.

Since withdrawals from either Burnt or Marie Lakes affects all the downstream lake levels and streamflows in the sub-basin, it is necessary to summarize each simulation for all affected lakes and outflows. The results of these simulations are presented for Burnt Lake in Tables 4.6.1 to 4.6.8 and Marie Lake in Tables 4.6.9 to 4.6.12. The summary table for the Ethel Lake simulation is 4.6.13. The variation in lake levels and streamflows for Burnt and Marie Lakes and their release channels for

Table 4.5.1

MANATOKAN LAKE
SIMULATION SUMMARY

Unattended Outlet
Maximum Annual Withdrawal = 540 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	Winter	Summer
Maximum	556.87		556.88	556.03	556.88
10% Exceedance	555.89	556.09	556.00	555.54	556.21
Median	555.35	555.55	555.43	555.36	555.57
90% Exceedance	555.20	555.20	555.26	555.24	555.32
Minimum	554.88	554.88	554.93	554.93	555.05

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	0.19	61		56	
May	0.60	78		79	
June	0.35	78	75	77	73
July	0.29	79		76	
August	0.23	74		70	
September	0.11	76		77	
October	0.14	59		62	
November	0.16	59		53	
December	0.15	58	59	59	58
January	0.13	59		59	
February	0.12	61		58	
March	0.11	60		55	

Average Annual Change in PMF Achievement -2%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	11.7	11.8

DEFICITS

Mean Annual	2.0 cu dam
Withdrawal	0.5 %
Duration, Deficit > 10%	7 weeks
Duration, Deficit > 30%	6 weeks

Table 4.5.2

MANATOKAN LAKE
SIMULATION SUMMARY

Ducks Unlimited Outlet
Maximum Annual Withdrawal = 0 cu dam

LAKE LEVELS (m)		PREFERRED/		REGULATED	
	NATURAL	ACCEPTABLE	Annual	Winter	Summer
Maximum	556.87		556.22	555.63	556.22
10% Exceedance	555.89	556.09	555.62	555.48	555.68
Median	555.35	555.55	555.42	555.40	555.48
90% Exceedance	555.20	555.20	555.38	555.37	555.39
Minimum	554.88	554.88	555.04	555.04	555.16

STREAMFLOWS	PMF	% OF TIME PMF EXCEEDED			
	(cms)	Natural		Regulated	
April	0.19	61	75	75	66
May	0.60	78		79	
June	0.35	78		67	
July	0.29	79		58	
August	0.23	74		56	
September	0.11	76		64	
October	0.14	59	59	54	52
November	0.16	59		61	
December	0.15	58		55	
January	0.13	59		52	
February	0.12	61		42	
March	0.11	60		49	

Average Annual Change in PMF Achievement -8%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	11.7	12.3

DEFICITS

Mean Annual	N/A
Withdrawal	N/A
Duration, Deficit > 10%	N/A
Duration, Deficit > 30%	N/A

Table 4.6.1

BURNT LAKE
SIMULATION SUMMARY

Unattended Outlet
Maximum Annual Withdrawal = 950 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	Winter	Summer
Maximum	662.69		662.73	662.71	662.73
10% Exceedance	662.49	662.69	662.69	662.66	662.70
Median	662.45	662.65	662.59	662.56	662.64
90% Exceedance	662.44	662.44	662.48	662.47	662.52
Minimum	662.35	662.35	662.35	662.42	662.35

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	0.15	56	75	23	72
May	0.21	83		71	
June	0.16	75		85	
July	0.03	83		87	
August	0.04	75		81	
September	0.00	77		83	
October	0.06	73	61	71	55
November	0.12	62		55	
December	0.09	57		61	
January	0.08	60		60	
February	0.05	57		50	
March	0.05	54		34	

Average Annual Change in PMF Achievement -4%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	5.8	8.6

DEFICITS

Mean Annual	12.0 cu dam
Withdrawal	1.3 %
Duration, Deficit > 10%	6 weeks
Duration, Deficit > 30%	6 weeks

Table 4.6.2

MAY LAKE
SIMULATION SUMMARY

Existing Outlet
Maximum Annual Withdrawal from Burnt Lake = 950 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	605.78	605.78	605.75	605.65	605.75
10% Exceedance	605.63	605.63	605.63	605.61	605.65
Median	605.60	605.60	605.60	605.60	605.60
90% Exceedance	605.57	605.57	605.57	605.54	605.58
Minimum	605.31	605.31	604.51	605.47	604.51

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		% OF TIME PMF EXCEEDED Regulated	
April	0.17	58	...	75	...
May	0.28	84	:	66	:
June	0.15	76	: 74	68	: 71
July	0.03	81	:	76	:
August	0.05	69	:	72	:
September	0.02	71	..:	67	..:
October	0.08	69	...	48	...
November	0.18	62	:	49	:
December	0.13	56	: 59	51	: 51
January	0.12	59	:	54	:
February	0.07	57	:	51	:
March	0.07	52	..:	55	..:

Average Annual Change in PMF Achievement -6%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	9.0	6.8

DEFICITS

Mean Annual	N/A
Withdrawal	N/A
Duration, Deficit > 10%	N/A
Duration, Deficit > 30%	N/A

Table 4.6.3

MARIE LAKE
SIMULATION SUMMARY

Existing Outlet
Maximum Annual Withdrawal from Burnt Lake = 950 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	574.20	574.40	574.31	573.95	574.31*
10% Exceedance	573.88	574.08	573.87	573.78	573.93
Median	573.69	573.89	573.68	573.68	573.69
90% Exceedance	573.54	573.54	573.54	573.52	573.56
Minimum	573.35	573.35	573.33	573.34	573.33

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		% OF TIME PMF EXCEEDED Regulated	
April	0.12	77		76	
May	0.28	76		66	
June	0.33	75	76	68	71
July	0.13	79		77	
August	0.12	75		72	
September	0.00	73		67	
October	0.06	55		48	
November	0.13	57		49	
December	0.24	60	58	51	51
January	0.30	59		54	
February	0.30	60		51	
March	0.28	59		55	

Average Annual Change in PMF Achievement -6%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	5.1	6.8

DEFICITS

Mean Annual	N/A
Withdrawal	N/A
Duration, Deficit > 10%	N/A
Duration, Deficit > 30%	N/A

Table 4.6.4

ETHEL LAKE
SIMULATION SUMMARY

Existing Outlet
Maximum Annual Withdrawal from Burnt Lake = 950 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED		
			Annual	Winter	Summer
Maximum	541.16	541.60	541.21	541.03	541.21
10% Exceedance	541.00	541.20	541.01	540.98	541.02
Median	540.96	541.16	540.96	540.96	540.97
90% Exceedance	540.85	540.85	540.84	540.83	540.87
Minimum	540.73	540.73	540.72	540.74	540.72

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED					
		Natural			Regulated		
April	0.17	73	...		70	...	
May	0.40	77	:		71	:	
June	0.36	73	:	76	67	:	71
July	0.14	80	:		77	:	
August	0.09	77	:		71	:	
September	0.05	74	..:		70	..:	
October	0.06	56	...		52	...	
November	0.06	59	:		53	:	
December	0.25	61	:	58	52	:	52
January	0.33	59	:		52	:	
February	0.33	58	:		51	:	
March	0.31	58	..:		52	..:	

Average Annual Change in PMF Achievement -6%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	6.4	7.9

DEFICITS	
Mean Annual	N/A
Withdrawal	N/A
Duration, Deficit > 10%	N/A
Duration, Deficit > 30%	N/A

Table 4.6.5

BURNT LAKE
SIMULATION SUMMARY

Fully Controlled Outlet
Maximum Annual Withdrawal = 1580 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	Winter	Summer
Maximum	662.69		663.17	662.69	663.17
10% Exceedance	662.49	662.69	662.69	662.69	662.69
Median	662.45	662.63	662.67	662.63	662.69
90% Exceedance	662.44	662.44	662.48	662.46	662.51
Minimum	662.35	662.35	662.39	662.40	662.39

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural			Regulated		
April	0.15	56	...		68	...	
May	0.21	83	:		85	:	
June	0.16	75	:	75	84	:	85
July	0.03	83	:		89	:	
August	0.04	75	:		88	:	
September	0.00	77	..:		97	..:	
October	0.06	73	...		78	...	
November	0.12	62	:		77	:	
December	0.09	57	:	61	68	:	70
January	0.08	60	:		67	:	
February	0.05	57	:		67	:	
March	0.05	54	..:		60	..:	

Average Annual Change in PMF Achievement +10%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	5.8	4.1

DEFICITS

Mean Annual	10.0 cu dam
Withdrawal	0.6 %
Duration, Deficit > 10%	4 weeks
Duration, Deficit > 30%	3 weeks

Table 4.6.6

HAY LAKE
SIMULATION SUMMARY

Existing Outlet
Maximum Annual Withdrawal from Burnt Lake = 1580 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	Winter	Summer
Maximum	605.78	605.78	605.74	605.64	605.74
10% Exceedance	605.63	605.63	605.63	605.60	605.65
Median	605.60	605.60	605.60	605.60	605.60
90% Exceedance	605.57	605.57	605.57	605.55	605.57
Minimum	605.31	605.31	604.48	605.48	604.50

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	0.17	58	74	54	67
May	0.28	84		78	
June	0.15	76		71	
July	0.03	81		74	
August	0.05	69		62	
September	0.02	71		61	
October	0.08	69	59	60	52
November	0.18	62		55	
December	0.13	56		54	
January	0.12	59		50	
February	0.07	57		52	
March	0.07	52		41	

Average Annual Change in PMF Achievement -7%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	9.0	6.6

DEFICITS

Mean Annual	N/A
Withdrawal	N/A
Duration, Deficit > 10%	N/A
Duration, Deficit > 30%	N/A

Table 4.6.7

MARIE LAKE
SIMULATION SUMMARY

Existing Outlet
Maximum Annual Withdrawal from Burnt Lake = 1580 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	574.20	574.40	574.18	573.95	574.18
10% Exceedance	573.88	574.08	573.86	573.77	573.92
Median	573.69	573.89	573.68	573.67	573.69
90% Exceedance	573.54	573.54	573.53	573.51	573.55
Minimum	573.35	573.35	573.32	573.32	573.32

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		% OF TIME PMF EXCEEDED Regulated	
April	0.12	77		75	
May	0.28	76		66	
June	0.33	75	76	64	69
July	0.13	79		76	
August	0.12	75		68	
September	0.00	73		65	
October	0.06	55		48	
November	0.13	57		48	
December	0.24	60	58	47	48
January	0.30	59		49	
February	0.30	60		48	
March	0.28	59		51	

Average Annual Change in PMF Achievement -8%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	5.1	4.7

DEFICITS

Mean Annual	N/A
Withdrawal	N/A
Duration, Deficit > 10%	N/A
Duration, Deficit > 30%	N/A

Table 4.6.8

ETHEL LAKE
SIMULATION SUMMARY

Existing Outlet
Maximum Annual Withdrawal from Burnt Lake = 1580 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	541.16	541.60	541.14	541.03	541.14
10% Exceedance	541.00	541.20	541.00	540.98	541.02
Median	540.96	541.16	540.96	540.95	540.97
90% Exceedance	540.85	540.85	540.84	540.83	540.86
Minimum	540.73	540.73	540.71	540.72	540.71

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		% OF TIME PMF EXCEEDED Regulated	
April	0.17	73		68	
May	0.40	77		69	
June	0.36	73	76	67	70
July	0.14	80		76	
August	0.09	77		71	
September	0.05	74		68	
October	0.06	56		51	
November	0.06	59		52	
December	0.25	61	58	50	48
January	0.33	59		47	
February	0.33	58		42	
March	0.31	58		45	

Average Annual Change in PMF Achievement -8%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	6.4	5.7

DEFICITS

Mean Annual	N/A
Withdrawal	N/A
Duration, Deficit > 10%	N/A
Duration, Deficit > 30%	N/A

Table 4.6.9

MARIE LAKE
SIMULATION SUMMARY

Unattended Outlet
Maximum Annual Withdrawal = 1200 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	Winter	Summer
Maximum	574.20	574.30	574.30	574.11	574.30
10% Exceedance	573.88	574.08	574.05	574.01	574.09
Median	573.69	573.89	573.89	573.86	573.92
90% Exceedance	573.54	573.54	573.73	573.72	573.75
Minimum	573.35	573.35	573.47	573.49	573.47

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	0.12	77	76	88	76
May	0.28	76		69	
June	0.33	75		54	
July	0.13	79		78	
August	0.12	75		80	
September	0.00	73		90	
October	0.06	55	58	66	55
November	0.13	57		58	
December	0.24	60		52	
January	0.30	59		49	
February	0.30	60		50	
March	0.28	59		55	

Average Annual Change in PMF Achievement -2%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	5.1	9.6

DEFICITS

Mean Annual	0.0 cu dam
Withdrawal	0.0 %
Duration, Deficit > 10%	0 weeks
Duration, Deficit > 30%	0 weeks

Table 4.6.10

ETHEL LAKE
SIMULATION SUMMARY

Existing Outlet
Maximum Annual Withdrawal from Marie Lake = 1200 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	541.16	541.60	541.29	541.04	541.29
10% Exceedance	541.00	541.20	541.00	540.97	541.02
Median	540.96	541.16	540.96	540.95	540.96
90% Exceedance	540.85	540.85	540.87	540.87	540.90
Minimum	540.73	540.73	540.73	540.75	540.73

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		% OF TIME PMF EXCEEDED Regulated	
April	0.17	73	76	72	75
May	0.40	77		67	
June	0.36	73		61	
July	0.14	80		79	
August	0.09	77		82	
September	0.05	74		88	
October	0.06	56	58	69	53
November	0.06	59		63	
December	0.25	61		57	
January	0.33	59		42	
February	0.33	58		38	
March	0.31	58		49	

Average Annual Change in PMF Achievement -3%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	6.4	10.9

DEFICITS

Mean Annual	N/A
Withdrawal	N/A
Duration, Deficit > 10%	N/A
Duration, Deficit > 30%	N/A

Table 4.6.11

MARIE LAKE
SIMULATION SUMMARY

Fully Controlled Outlet
Maximum Annual Withdrawal = 3630 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	574.20	574.30	574.30	574.08	574.30
10% Exceedance	573.88	574.08	574.08	574.08	574.08
Median	573.69	573.89	573.97	573.93	573.99
90% Exceedance	573.54	573.54	573.69	573.68	573.70
Minimum	573.35	573.35	573.41	573.43	573.41

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		% OF TIME PMF EXCEEDED Regulated	
April	0.12	77		90	
May	0.28	76		92	
June	0.33	75	76	89	88
July	0.13	79		88	
August	0.12	75		85	
September	0.00	73		85	
October	0.06	55		67	
November	0.13	57		65	
December	0.24	60	58	51	70
January	0.30	59		67	
February	0.30	60		80	
March	0.28	59		90	
Average Annual Change in PMF Achievement				+12%	
Absolute Minimum (cms)		0.0		0.0	
Absolute Maximum (cms)		5.1		6.1	

DEFICITS

Mean Annual	16.0 cu dam
Withdrawal	0.5 %
Duration, Deficit > 10%	3 weeks
Duration, Deficit > 30%	3 weeks

Table 4.6.12

ETHEL LAKE
SIMULATION SUMMARY

Existing Outlet
Maximum Annual Withdrawal from Marie Lake = 3630 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	541.16	541.60	541.21	541.07	541.21
10% Exceedance	540.99	541.20	541.00	540.97	541.02
Median	540.96	541.16	540.95	540.95	540.95
88% Exceedance	540.85	540.85	540.84	540.83	540.90
Minimum	540.73	540.73	540.75	540.77	540.75

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	0.17	73		41	
May	0.40	77		62	
June	0.36	73	76	60	58
July	0.14	80		68	
August	0.09	77		65	
September	0.05	74		50	
October	0.06	56		31	
November	0.06	59		36	
December	0.25	61	58	45	38
January	0.33	59		38	
February	0.33	58		40	
March	0.31	58		38	

Average Annual Change in PMF Achievement -19%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	6.4	7.9

DEFICITS

Mean Annual	N/A
Withdrawal	N/A
Duration, Deficit > 10%	N/A
Duration, Deficit > 30%	N/A

Table 4.6.13

ETHEL LAKE
SIMULATION SUMMARY

Unattended Outlet
Maximum Annual Withdrawal = 700 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	541.16	541.60	541.60	541.31	541.60
10% Exceedance	541.00	541.20	541.26	541.22	541.30
Median	540.96	541.16	541.14	541.14	541.16
94% Exceedance	540.85	540.85	540.96	540.94	540.99
Minimum	540.73	540.73	540.73	540.76	540.73

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		% OF TIME PMF EXCEEDED Regulated	
April	0.17	73		70	
May	0.40	77		68	
June	0.36	73	76	72	73
July	0.14	80		81	
August	0.09	77		76	
September	0.05	74		71	
October	0.06	56		53	
November	0.06	59		56	
December	0.25	61	58	54	53
January	0.33	59		50	
February	0.33	58		51	
March	0.31	58		52	

Average Annual Change in PMF Achievement -4%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	6.4	6.0

DEFICITS

Mean Annual	3.1 cu dam
Withdrawal	0.4 %
Duration, Deficit > 10%	4 weeks
Duration, Deficit > 30%	4 weeks

unattended and fully controlled outlets on Burnt and Marie Lakes respectively are presented in Plates 4.6.1 to 4.6.2. The variation of water level and outflow for Ethel Lake with an unattended outlet is presented in Plate 4.6.3.

The simulation results indicate that Marie Lake is the best candidate for an industrial withdrawal since it provides the highest rate of withdrawal and has the least effect on the flows and lake levels in the Marie Creek sub-basin. The maximum withdrawal from Burnt Lake using either an unattended or fully controlled outlet, produces an unacceptably low minimum lake level in May Lake and lower than acceptable winter flows in Marie Creek. The annual withdrawal of 3630 dam^3 from Marie Lake using a controlled outlet causes an unacceptable reduction in the low flows in Marie Creek downstream of Ethel Lake. Regulation of lakes and outflows downstream from the point of withdrawal could alleviate the above problems.

An annual withdrawal approaching 1200 dam^3 from Marie Lake is the maximum available in the Marie Creek sub-basin if only one structure is considered and all operating criteria are to be satisfied. Ethel Lake has the least potential for industrial withdrawal.

4.7 COLD LAKE

The Cold Lake sub-basin comprises the reach of Cold River immediately downstream of Cold Lake, the Martineau River and Primrose Lake. This sub-basin is not physically connected to the Beaver River within Alberta but the Cold River joins the Beaver River in Saskatchewan. The Cold River is an interprovincial stream and as such may come under the Apportionment Agreement between Alberta, Saskatchewan and Manitoba. The analysis of the Cold Lake sub-basin, therefore, considered that Alberta could reduce the natural flow to Saskatchewan by 32% over a calendar year. The apportionment of this amount of flow to Alberta was based on allocation of 50% of the flow originating from that portion of the drainage basin within Alberta.

The sensitivity of the maximum withdrawal volume to apportionment requirements required that the natural outflows from Cold Lake be as accurate as possible. The original hydrology, as prepared by Northwest Hydraulic Consultants, provided the best estimate of inflows to Cold and Primrose Lakes and flows in the Medley River but did not produce Cold River flows consistent with the recorded water surface elevations of Cold Lake. The inflows to Cold Lake were therefore recalculated and since Primrose Lake and the Medley River were no longer considered candidates for industrial withdrawals, the total inflow to Cold Lake, including the Medley and Martineau Rivers was used to represent the inflow hydrology. These inflows are reported in Appendix B.

The maximum industrial withdrawals from Cold Lake were evaluated for three scenarios;

1. the existing,unaltered outlet structure satisfying the apportionment requirements only
2. an unattended structure regulating lake levels and outflows to satisfy all criteria including apportionment
3. a fully controlled outlet satisfying all criteria

In all three scenarios, a municipal withdrawal of 10,000 dam^3 per annum was assumed to occur, and take precedence over, any industrial withdrawal. The results of the simulations are presented in Tables 4.7.1 to 4.7.3. The variation in the water levels of Cold Lake and the flows in the Cold River are presented in Plate 4.7.

The results of the simulation of Cold Lake with the existing natural outlet indicate a maximum annual withdrawal of 20,000 dam^3 can be made from Cold Lake without appreciably lowering lake levels or flows in the Cold River. Apportionment to Saskatchewan of 68% of the natural flow in the Cold River is achieved but streamflow and lake levels do not satisfy the criteria. After discussions with Alberta Environment, the lake level criteria were set such that the change in minimum lake level should not exceed 2.5 cm and this criterion was met.

Table 4.7.1

COLD LAKE
SIMULATION SUMMARY

Existing Outlet
Maximum Annual Withdrawal* = 20000 cu dam
with 32% Apportionment

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	Winter	Summer
Maximum	535.78	535.64	535.77	535.55	535.77
10% Exceedance	535.26	535.35	535.26	535.12	535.36
Median	534.98	535.18	534.96	534.88	535.03
90% Exceedance	534.76	534.76	534.75	534.72	534.85
Minimum	534.57	534.57	534.55	534.55	534.60

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	6.71	81	74	76	70
May	11.50	75		71	
June	16.80	77		69	
July	17.20	77		70	
August	17.10	68		68	
September	14.70	66		63	
October	11.80	65	60	63	56
November	8.93	58		56	
December	6.38	59		55	
January	7.07	57		57	
February	7.43	61		53	
March	7.57	62		52	

Average Annual Change in PMF Achievement -4%

	Natural	Regulated
Absolute Minimum (cms)	1.0	1.0
Absolute Maximum (cms)	68.6	68.1

DEFICITS

Mean Annual	43.6 cu dam
Withdrawal	0.4 %
Duration, Deficit > 10%	5 weeks
Duration, Deficit > 30%	5 weeks

* includes municipal withdrawal of 8,500 cu dam

Table 4.7.2

COLD LAKE
SIMULATION SUMMARY

Unattended Outlet
Maximum Annual Withdrawal* = 48600 cu dam
with 32% Apportionment

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	535.78	535.64	535.78	535.55	535.78
10% Exceedance	535.26	535.35	535.47	535.40	535.53
Median	534.98	535.18	535.10	535.01	535.19
90% Exceedance	534.76	534.76	534.88	534.84	534.97
Minimum	534.57	534.57	534.63	534.63	534.65

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	6.71	81		68	
May	11.50	75		65	
June	16.80	77	74	68	70
July	17.20	77		75	
August	17.10	68		73	
September	14.70	66		69	
October	11.80	65		70	
November	8.93	58		62	
December	6.38	59	60	58	58
January	7.07	57		57	
February	7.43	61		52	
March	7.57	62		52	

Average Annual Change in PMF Achievement -3%

	Natural	Regulated
Absolute Minimum (cms)	1.0	2.1
Absolute Maximum (cms)	68.6	110.7

DEFICITS

Mean Annual	0.0 cu dam
Withdrawal	0.0 %
Duration, Deficit > 10%	0 weeks
Duration, Deficit > 30%	0 weeks

* includes municipal withdrawal of 10,000 cu dam

Table 4.7.3

COLD LAKE
SIMULATION SUMMARY

Fully Controlled Outlet
Maximum Annual Withdrawal* = 73200 cu dam
with 32% Apportionment

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	Winter	Summer
Maximum	535.78	535.64	535.78	535.50	535.78
10% Exceedance	535.26	535.35	535.50	535.50	535.50
Median	534.98	535.18	535.25	535.16	535.36
90% Exceedance	534.76	534.76	534.83	534.74	534.92
Minimum	534.57	534.57	534.55	534.55	534.59

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	6.71	81		55	
May	11.50	75		75	
June	16.80	77	74	89	81
July	17.20	77		92	
August	17.10	68		89	
September	14.70	66		85	
October	11.80	65		85	
November	8.93	58		85	
December	6.38	59	60	85	74
January	7.07	57		82	
February	7.43	61		66	
March	7.57	62		42	

Average Annual Change in PMF Achievement +10%

	Natural	Regulated
Absolute Minimum (cms)	1.0	1.0
Absolute Maximum (cms)	68.6	96.9

DEFICITS

Mean Annual	404.0 cu dam
Withdrawal	0.6 %
Duration, Deficit > 10%	4 weeks
Duration, Deficit > 30%	4 weeks

* includes municipal withdrawal of 10,000 cu dam

The PMF's are not achieved as often as the natural situation but the difference amounts to only 6%.

The unattended outlet provides 48,600 dam^3 of water for annual withdrawal while satisfying the streamflow criteria and apportionment. The preferred maximum lake level is not achieved but the regulated lake level does not exceed that highest natural level. Regulated minimum levels are higher than natural. Increased withdrawals from the lake are prohibited by the apportionment requirement, combined with maintenance of a maximum lake level at or below the natural value.

A withdrawal of 73,200 dam^3 is feasible from Cold Lake with a fully controlled outlet on the Cold River. Apportionment and streamflow criteria are satisfied but lake levels tend to be higher than the preferred/acceptable values. The maximum regulated lake level does not however surpass the natural maximum.

4.8 MOOSELAKE RIVER

The Mooselake River sub-basin, for the purposes of water balance modelling in this study, consists of Moose Lake and the downstream reach of Mooselake River to the Beaver River. Moose Lake is currently used as a source for municipal water supplies. An annual requirement of 3000 dam^3 was therefore set aside for municipal purposes in the simulation model. Since Moose Lake is an important recreational lake in the Region and high water levels are a chronic problem, emphasis was placed on reducing high and increasing low lake levels.

The summarized results from simulations with an unattended and fully controlled outlet are displayed in Tables 4.8.1 and 4.8.2. Graphs of the variation in lake levels and outflows for both regulation conditions are presented in Plate 4.8. In both situations, channel

Table 4.8.1

MOOSE LAKE
SIMULATION SUMMARY

Unattended Outlet
Maximum Annual Withdrawal = 3000 cu dam
(Municipal Only)

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	534.12	533.21	533.71	533.20	533.71
10% Exceedance	533.27	533.15	533.17	533.13	533.23
Median	532.94	533.14	533.00	532.97	533.06
90% Exceedance	532.78	532.94	532.86	532.84	532.88
Minimum	532.56	532.77	532.56	532.56	532.63

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		% OF TIME PMF EXCEEDED Regulated	
April	0.21	71	...	57	...
May	0.43	78	:	70	:
June	0.46	76	: 74	72	: 64
July	0.64	71	:	57	:
August	0.41	73	:	65	:
September	0.27	75	..:	60	..:
October	0.23	65	...	51	...
November	0.19	58	:	49	:
December	0.20	59	: 60	50	: 52
January	0.24	59	:	54	:
February	0.22	60	:	54	:
March	0.21	61	..:	54	..:

Average Annual Change in PMF Achievement -9%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	7.8	14.9

DEFICITS

Mean Annual	0.0 cu dam
Withdrawal	0.0 %
Duration, Deficit > 10%	0 weeks
Duration, Deficit > 30%	0 weeks

Table 4.8.2

MOOSE LAKE
SIMULATION SUMMARY

Fully Controlled Outlet
Maximum Annual Withdrawal* = 4600 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	534.12	533.21	533.77	533.47	533.77
10% Exceedance	533.27	533.15	533.47	533.47	533.47
Median	532.94	533.14	533.32	533.23	533.38
90% Exceedance	532.78	532.94	533.02	533.01	533.06
Minimum	532.56	532.77	532.59	532.59	532.67

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		% OF TIME PMF EXCEEDED Regulated	
April	0.21	71		87	
May	0.43	78		89	
June	0.46	76	74	88	85
July	0.64	71		82	
August	0.41	73		80	
September	0.27	75		83	
October	0.23	65		72	
November	0.19	58		67	
December	0.20	59	60	53	71
January	0.24	59		75	
February	0.22	60		79	
March	0.21	61		81	

Average Annual Change in PMF Achievement +11%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	7.8	16.4

DEFICITS

Mean Annual	2.0 cu dam
Withdrawal	0.2 %
Duration, Deficit > 10%	2 weeks
Duration, Deficit > 30%	2 weeks

* includes municipal withdrawal of 3000 cu dam

improvements are required downstream from the outlet from Moose Lake. The extent of these improvements can be gauged from the stage/discharge curves for each outlet in Appendix B.

In these simulations, neither outlet satisfies both the lake level and streamflow criteria. The fully controlled outlet is operated to improve the outflows by the required'+10%' and maximize the withdrawal. The water levels, as a result are generally higher than the preferred/ levels although the minimum level is below the desired value. The preferred 10% exeedance value is actually exceeded 72% of the time. It should be noted however that the maximum lake level is still less than the natural value.

The unattended outlet produces lake levels which are more compatible with the preferred values but achievement of the PMF is reduced by 8 to 10%. No industrial withdrawal was available in this instance. The lake levels are stabilized, particularly in the summer when 85% of water levels are within the desired range of 532.83 to 533.23. Reduction of the maximum lake level from 533.71 is a function of the extent of channel improvements. The unattended outlet presented here almost doubles the absolute maximum flow during the twenty-six years of simulation. Additional channel improvements would increase this flow.

In summary, Moose Lake is not a good candidate for an industrial withdrawal and given the municipal withdrawal, low levels within the lake are unavoidable from time to time. Significant reductions in high water levels can be made with capacity improvements of the outflow channel. An unattended structure can be used to permit municipal withdrawals and stabilize lake levels.

4.9 MURIEL CREEK

The Muriel Creek sub-basin includes two lakes, Charlotte and Muriel. Charlotte Lake was not considered for an industrial withdrawal but Muriel Lake was simulated to determine the maximum available withdrawal. The natural outflow from Muriel Lake is such that the PMF values for all months is zero. In fact, 45% of the time in winter, and 30% of the time in summer the natural flows are zero. The streamflow criteria were therfore adjusted to permit a reduction in the median annual volume in Muriel Creek downstream of Muriel Lake by 10% for an unattended outlet and increasing the median annual volume by 10% for the fully controlled outlet.

The simulation of an unattended outlet demonstrated that the deficit criteria could not be satisfied. The mean annual deficit exceeded 10% and the duration of a complete cut-off of the withdrawal exceeded one year. It was obvious that a fully controlled outlet would fare no better than the unattended and no analysis was made. Muriel Lake should not be considered a candidate for industrial or municipal withdrawal.

4.10 CARIBOU LAKE

Caribou Lake is located on the Sand River above the confluence with the Wolf River, in the Cold Lake Weapons Range. The Lake is inaccessible and not used for recreational pursuits. Although it is located at some distance from the majority of the industrial withdrawals, the Lake could be used to regulate the Sand such that a withdrawal could be made at a downstream point without violating the streamflow criteria. The usual analyses with an unattended and fully controlled outlet were therefore conducted.

The results of the two simulations are summarized in Tables 4.10.1 and 4.10.2. Variations in lake levels and outflow with the two types of outlet structures are graphed in Plate 4.10.

Table 4.10.1

CARIBOU LAKE
SIMULATION SUMMARY

Unattended Outlet
Maximum Annual Withdrawal = 6300 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	Winter	Summer
Maximum	634.38		634.78	634.14	634.78
10% Exceedance	633.48	633.98	633.96	633.77	634.01
Median	633.22	633.72	633.41	633.16	633.77
90% Exceedance	633.02	633.02	633.04	632.98	633.16
Minimum	632.85	632.85	632.85	632.85	632.94

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	2.49	56	74	42	72
May	3.36	78		77	
June	2.37	76		78	
July	1.58	79		81	
August	1.70	75		75	
September	1.12	81		80	
October	1.50	78	62	77	55
November	1.89	61		64	
December	1.16	56		56	
January	0.71	60		54	
February	0.58	59		47	
March	0.47	58		36	

Average Annual Change in PMF Achievement -4%

Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	90.3	88.9

DEFICITS

Mean Annual	28.0 cu dam
Withdrawal	0.4 %
Duration, Deficit > 10%	7 weeks
Duration, Deficit > 30%	6 weeks

Table 4.10.2

CARIBOU LAKE
SIMULATION SUMMARY

Fully Controlled Outlet
Maximum Annual Withdrawal = 6300 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	REGULATED Winter	REGULATED Summer
Maximum	634.38		634.46	634.02	634.46
10% Exceedance	633.48	633.98	633.97	633.85	634.01
Median	633.22	633.72	633.85	633.82	633.85
90% Exceedance	633.02	633.02	633.05	633.08	633.00
Minimum	632.85	632.85	632.88	632.88	632.97

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		% OF TIME PMF EXCEEDED Regulated	
April	2.49	56		82	
May	3.36	78		90	
June	2.37	76	74	86	87
July	1.58	79		87	
August	1.70	75		87	
September	1.12	81		92	
October	1.50	78		83	
November	1.89	61		77	
December	1.16	56	62	65	70
January	0.71	60		64	
February	0.58	59		66	
March	0.47	58		66	

Average Annual Change in PMF Achievement +10%

Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	90.3	92.2

DEFICITS

Mean Annual	0.0 cu dam
Withdrawal	0.0 %
Duration, Deficit > 10%	0 weeks
Duration, Deficit > 30%	0 weeks

Both structures permit the same magnitude of withdrawal. The only significant difference is the fully controlled outlet has no deficits whereas the withdrawal is almost shut-off for a six week period with the unattended outlet. The two withdrawals are equal even though the fully controlled outlet has more flexibility and can store more water in the Lake during high flow. The stipulation that PMF's must be achieved or exceeded 10% more often than in the natural case forces the fully controlled outlet to discharge more water during low flow sequences. The median water level with the fully controlled outlet exceeds the desired value by 13cm.

Caribou Lake is, hydrologically, a good candidate for industrial water supply but its distance from the probable point of use and its location within a weapons range argues against its regulation for industrial use.

4.11 REITA CREEK

The Reita Creek sub-basin includes two sizeable lakes, Angling and Reita. Both lakes were analyzed to determine the maximum available withdrawal. The sub-basin is hydrologically similar to Muriel Creek. Reita Creek, downstream of Reita Lake has zero flow in more than 50% of the months simulated. The streamflow criteria were adjusted in a manner similar to Muriel Creek but it was not possible to design any structure or operating policy which would satisfy the revised criteria. In particular, annual deficits exceeded 10%, and durations of complete shut-off of the withdrawal exceeded one year.

Angling Lake is downstream of Reita Lake and has more inflow. Useful PMF's could be determined and an unattended outlet was designed which satisfied all criteria. The results of this simulation are presented in Table 4.11.1. It was not possible to meet the more stringent criteria with a fully controlled outlet. The variation of lake levels and outflows with the unattended outlet are presented in Plate 4.11 .

Table 4.11.1

ANGLING LAKE
SIMULATION SUMMARY

Unattended Outlet
Maximum Annual Withdrawal = 950 cu dam

LAKE LEVELS (m)	NATURAL	PREFERRED/ ACCEPTABLE	REGULATED Annual	Winter	Summer
Maximum	557.56		557.60	557.33	557.60
10% Exceedance	557.11	557.31	557.31	557.24	557.37
Median	556.91	557.11	557.08	557.06	557.15
90% Exceedance	556.82	556.82	556.90	556.89	556.93
Minimum	556.74	556.74	556.76	556.76	556.77

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural			Regulated		
April	0.05	73	...		49	...	
May	0.17	77	:		65	:	
June	0.10	76	:	74	72	:	70
July	0.11	72	:		75	:	
August	0.05	73	:		69	:	
September	0.01	71	..:		88	..:	
October	0.01	59	...		93	...	
November	0.01	59	:		92	:	
December	0.03	60	:	59	55	:	56
January	0.06	59	:		36	:	
February	0.07	57	:		28	:	
March	0.06	60	..:		32	..:	

Average Annual Change in PMF Achievement -4%

	Natural	Regulated
Absolute Minimum (cms)	0.0	0.0
Absolute Maximum (cms)	4.1	4.2

DEFICITS

Mean Annual	4.0 cu dam
Withdrawal	0.5 %
Duration, Deficit > 15%	0 weeks
Duration, Deficit > 34%	0 weeks

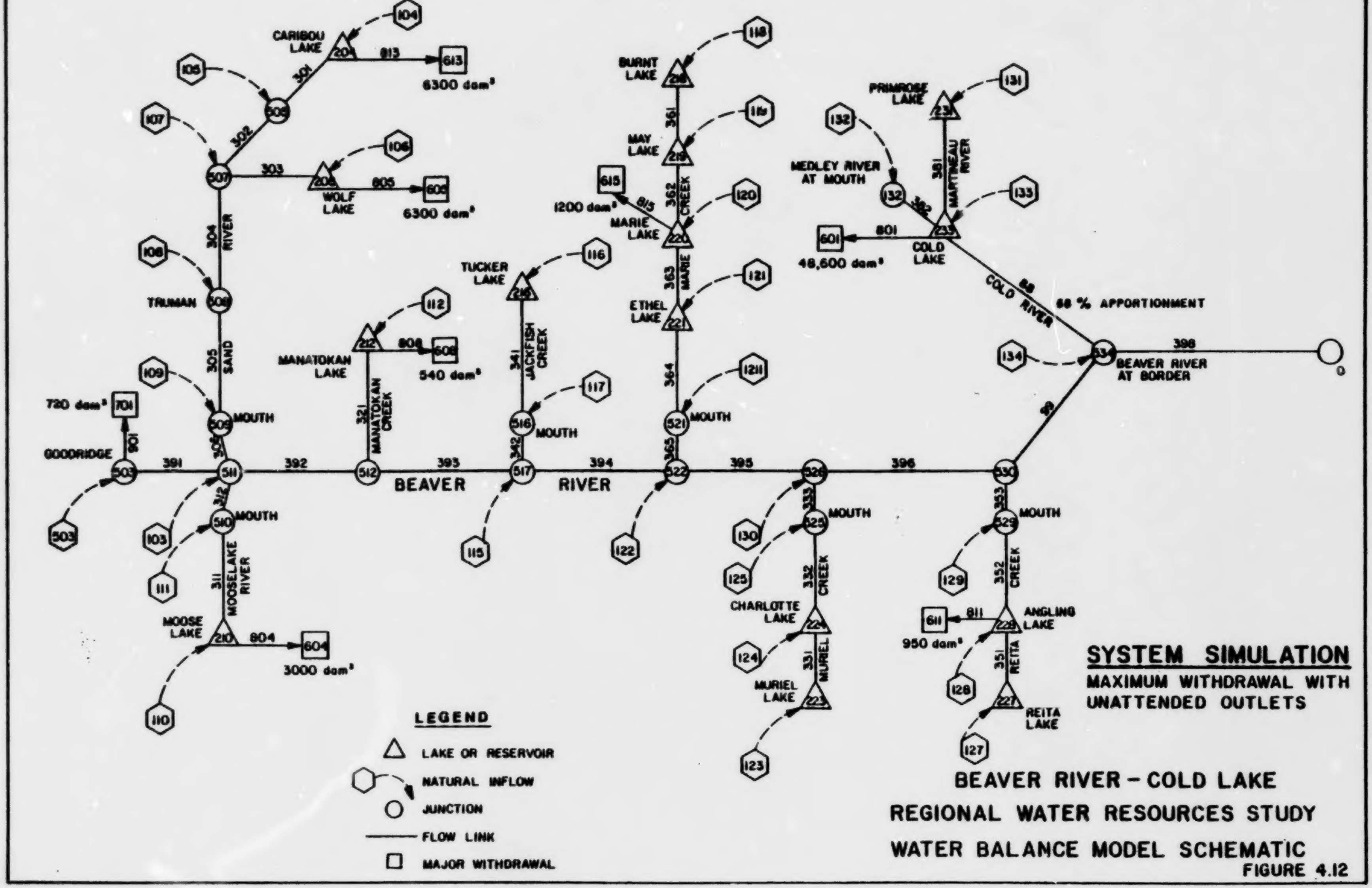
The results indicate complete satisfaction of all criteria with an increase of the maximum water level of 4cm. The magnitude of the withdrawal is comparable to other lakes in sub-area A such as Burnt, Ethel and Manatokan. Angling Lake is therefore a fair candidate for industrial withdrawal.

4.12 SYSTEM SIMULATION: UNATTENDED OUTLETS

A simulation of the entire Beaver River-Cold Lake water resource system was conducted to assess the overall effects of withdrawing the maximum available amount of water from lakes with unattended outlets. Figure 4.12 displays the system schematic with the withdrawals superimposed. The maximum withdrawals are consistent with that determined in the sub-basin analysis. On Marie Creek, a withdrawal was made from Marie Lake only, since this was the largest single withdrawal in the Marie Creek sub-basin and will have the greatest effect on flows in the Beaver River. Only the lakes having a withdrawal were regulated. The remaining lakes were either not considered for an industrial withdrawal or the sub-basin analysis determined that no withdrawal could be made without violating the operating criteria.

The results of the simulation are identical within each sub-basin to the results presented in the respective sub-basin analysis. The results of interest relate to flows in the Sand and Beaver Rivers. The flows of the Sand at its mouth and the Beaver downstream of Reita Creek are compared to the natural flows in Table 4.12.1 and 4.12.2 and Plate 4.12. The most significant difference is the reduction in minimum and low flows in general, caused by withdrawals in the system. The PMF's are achieved within the criteria set out for streamflows but the predominant reduction in achievement level occurs in the winter, i.e. low flows.

For water quality purposes, the 1 in 10 year, 7 day low flow is a widely used index of low flow. The change in this index between the natural and the regulated conditions in this simulation for the Beaver River at the Saskatchewan Border and the Sand River at its mouth are;


CARIBOU LAKE
204
813
613
6300 dam³
104
105
505
301
302
107
507
303
208
WOLF LAKE
805
605
6300 dam³
106
304
RIVER
108
TRUMAN
508
305
SAND
109
509
MOUTH
720 dam³
701
901
GOODRIDGE
503
391
511
392
512
BEAVER
393
517
RIVER
394
522
395
526
396
530
503
103
111
312
510
MOUTH
311
MOOSELAKE RIVER
MOOSE LAKE
210
804
604
3000 dam³
110
MANATOKAN LAKE
212
112
808
608
540 dam³
321
MANATOKAN CREEK
TUCKER LAKE
216
116
341
JACKFISH CREEK
516
MOUTH
117
342
115
BURNT LAKE
218
118
361
MAY LAKE
219
119
362
CREEK
615
1200 dam³
815
MARIE LAKE
220
120
363
MARIE
ETHEL LAKE
221
121
364
521
MOUTH
1211
365
122
PRIMROSE LAKE
231
131
132
MEDLEY RIVER AT MOUTH
132
381
MARTINEAU RIVER
382
133
601
801
COLD LAKE
233
48,600 dam³
COLD RIVER
88
68 % APPORTIONMENT
134
534
398
BEAVER RIVER AT BORDER
0
38
130
333
525
MOUTH
125
332
CREEK
CHARLOTTE LAKE
224
124
331
MURIEL
MURIEL LAKE
223
123
353
529
MOUTH
129
352
CREEK
611
811
950 dam³
228
ANGLING LAKE
128
351
REITA
227
REITA LAKE
127
LEGEND
LAKE OR RESERVOIR
NATURAL INFLOW
JUNCTION
FLOW LINK
MAJOR WITHDRAWAL

SYSTEM SIMULATION

MAXIMUM WITHDRAWAL WITH
UNATTENDED OUTLETS

BEAVER RIVER - COLD LAKE
REGIONAL WATER RESOURCES STUDY
WATER BALANCE MODEL SCHEMATIC
FIGURE 4.12

Table 4.12.1

SYSTEM SIMULATION

Maximum Withdrawals
with Unattended Outlets

BEAVER RIVER d/s REITA CREEK

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural			Regulated		
April	23.40	57	...		52	...	
May	23.00	78	:		78	:	
June	18.80	71	:	73	69	:	73
July	10.60	78	:		80	:	
August	10.00	75	:		77	:	
September	8.03	79	..:		79	..:	
October	9.10	79	...		79	...	
November	10.20	56	:		55	:	
December	6.93	54	:	60	53	:	56
January	4.89	59	:		56	:	
February	4.43	57	:		47	:	
March	4.25	55	..:		46	..:	

Average Annual Change in PMF Achievement -2%

Absolute Minimum (cms)	0.22	0.12
Absolute Maximum (cms)	512.	523.

Table 4.12.2

SYSTEM SIMULATION

Maximum Withdrawals
with Unattended Outlets

SAND RIVER @ MOUTH

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED			
		Natural		Regulated	
April	8.74	56	74	49	75
May	12.60	77		75	
June	8.65	75		76	
July	5.29	78		81	
August	5.20	76		81	
September	3.79	81		83	
October	4.75	79	62	80	59
November	5.73	58		58	
December	3.59	56		57	
January	2.29	58		58	
February	1.78	62		56	
March	1.92	59		47	
Average Annual Change in PMF Achievement				-1%	
Absolute Minimum (cms)		0.17		0.00	
Absolute Maximum (cms)		272.		279.	

1:10 YEAR, WEEKLY LOW FLOWS

	Summer		Winter	
	Natural	Regulated	Natural	Regulated
	(m^3/s)		(m^3/s)	
Beaver @ Border	3.00	2.61	1.37	1.03
Sand @ Mouth	1.27	0.93	.41	.23

A comparison of the natural and regulated low flows shows a greater proportional reduction in the winter period. This situation arises because the withdrawals are made at a constant rate over the year while the winter streamflows are lesser than the summer.

The other area of interest in a system simulation is the relationship between regulated flows and the natural flows to Saskatchewan. On the Beaver River, the regulated flow to Saskatchewan always exceeds 50% of the natural flow. The Cold River conveys more than 68% of the natural flow to Saskatchewan, but the regulated flows approach the 68% value frequently. By illustration, a comparison is made between the critical annual flow, regulated and natural on both rivers.

Critical Annual Flow
(dam^3)

	Natural	Regulated	Reg/Nat.
Beaver River	233,700	217,600	0.93
Cold River	304,500	207,000	0.68

The critical annual flow on the Beaver is synonymous with the minimum annual flow. On the Cold River, the critical annual flow occurs the year following the minimum annual flow.

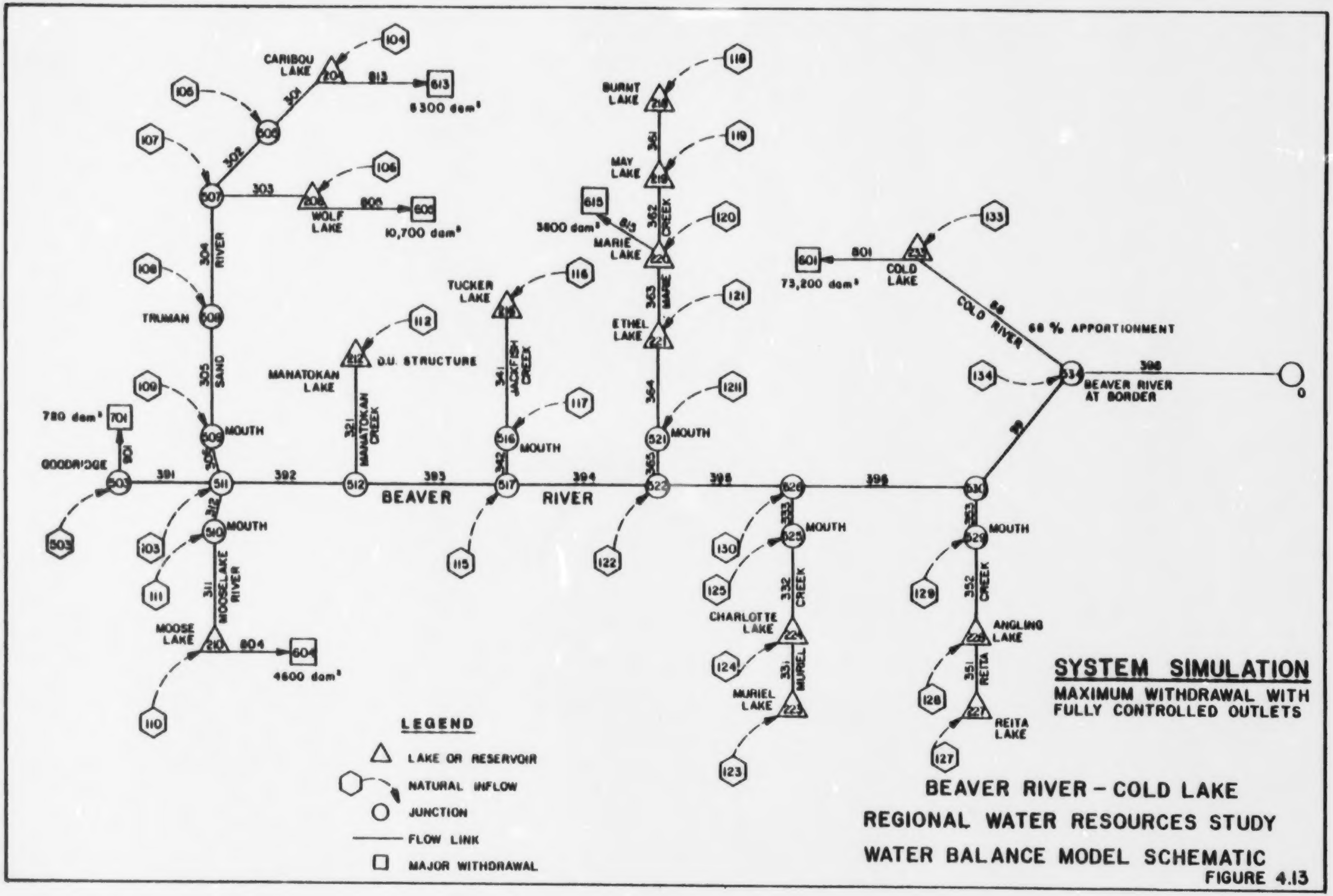
The system simulation shows that the maximum annual withdrawals from certain lakes with unattended outlets result in;

- significantly reduced minimum flows in the Beaver River and Sand River
- streamflow criteria are satisfied on all sub-basins and the main stem of the Beaver and Sand Rivers
- apportionment requirements with Saskatchewan are met

4.13 SYSTEM SIMULATION: FULLY CONTROLLED OUTLETS

A system simulation with fully controlled outlets was conducted to assess the results of maximum withdrawals from the regulated lakes. The locations of the lake withdrawals are shown on the system schematic, Figure 4.13. A withdrawal was made on Marie Lake in the Marie Creek sub-basin since it can contribute the largest withdrawal and therefore has the greatest effect on the overall system. The Ducks Unlimited structure was simulated on Manatokan Lake; a fully controlled outlet cannot satisfy the operating criteria. The other lakes, without withdrawals, were not regulated.

The results within each sub-basin are identical to the results presented in the respective sub-basin analysis. The major effects on the system can be assessed by examining flows in the Beaver, Sand and Cold Rivers. The flows of the Sand at its mouth and the Beaver downstream of Reita Creek are compared to the natural situation in Tables 4.13.1 and 4.13.2 and Plate 4.12. The Sand River flows, except for the absolute minimum flows are not significantly degraded by regulation. The Beaver shows a marked reduction in winter low flows although the absolute minimum flow is increased with regulation. The PMF's on the Beaver River are not achieved within the criteria set out for streamflows. The winter flows are too low. The controlled outlets on the individual lakes improve achievement time for PMF's by 10% on the outflow channel. This improvement is not reflected in the mainstem flows of the Beaver and Sand.



CARIBOU LAKE
204
104
813
613
5300 dam³
105
301
505
107
302
507
303
208
106
WOLF LAKE
808
608
10,700 dam³
304
RIVER
108
TRUMAN
506
305
SAND
109
509
MOUTH
780 dam³
701
901
GOODRIDGE
503
391
306
511
503
103
312
510
MOUTH
111
311
MOOSELAKE RIVER
MOOSE LAKE
210
804
604
4600 dam³
110
392
512
BEAVER
MANATOKAN LAKE
212
112
D.U. STRUCTURE
321
MANATOKAN CREEK
393
517
115
TUCKER LAKE
216
116
341
JACKFISH CREEK
516
117
MOUTH
342
394
RIVER
BURNT LAKE
218
118
361
MAY LAKE
219
119
362
CREEK
615
813
3800 dam³
MARIE LAKE
220
120
363
MARIE
ETHEL LAKE
221
121
364
521
1211
MOUTH
365
522
122
395
526
130
333
525
MOUTH
125
332
CREEK
CHARLOTTE LAKE
224
124
331
MURIEL
MURIEL LAKE
223
123
396
531
353
529
MOUTH
129
352
CREEK
ANGLING LAKE
228
128
351
REITA
227
REITA LAKE
127
601
801
73,200 dam³
233
COLD LAKE
133
88
COLD RIVER
68 % APPORTIONMENT
134
534
BEAVER RIVER AT BORDER
398
0
LEGEND
△ LAKE OR RESERVOIR
NATURAL INFLOW
○ JUNCTION
FLOW LINK
□ MAJOR WITHDRAWAL

SYSTEM SIMULATION

MAXIMUM WITHDRAWAL WITH
FULLY CONTROLLED OUTLETS

BEAVER RIVER - COLD LAKE
REGIONAL WATER RESOURCES STUDY
WATER BALANCE MODEL SCHEMATIC
FIGURE 4.13

Table 4.13.1

SYSTEM SIMULATION

Maximum Withdrawals
Fully Controlled Outlets

BEAVER RIVER d/s REITA CREEK

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural			Regulated		
April	23.40	57	...		55	...	
May	23.00	78	:		79	:	
June	18.80	71	:	73	67	:	71
July	10.60	78	:		77	:	
August	10.00	75	:		72	:	
September	8.03	79	..:		76	..:	
October	9.10	79	...		78	...	
November	10.20	56	:		50	:	
December	6.93	54	:	60	47	:	54
January	4.89	59	:		51	:	
February	4.43	57	:		48	:	
March	4.25	55	..:		47	..:	

Average Annual Change in PMF Achievement -4%

	Natural	Regulated
Absolute Minimum (cms)	0.22	0.28
Absolute Maximum (cms)	512.	535.

Table 4.13.2

SYSTEM SIMULATION

Maximum Withdrawals
Fully Controlled Outlets

SAND RIVER @ MOUTH

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	8.74	56		55	
May	12.60	77		76	
June	8.65	75	74	74	75
July	5.29	78		79	
August	5.20	76		78	
September	3.79	81		83	
October	4.75	79		79	
November	5.73	58		56	
December	3.59	56	62	56	61
January	2.29	58		57	
February	1.78	62		63	
March	1.92	59		54	

Average Annual Change in PMF Achievement 0%

	Natural	Regulated
Absolute Minimum (cms)	0.17	0.00
Absolute Maximum (cms)	272.	283.

The changes in the 1 in 10 year, weekly low flow from the natural flows are;

1:10 YEAR, WEEKLY LOW FLOWS

	Summer		Winter	
	Natural	Regulated	Natural	Regulated
	(m^3/s)		(m^3/s)	
Beaver @ Border	3.00	2.53	1.37	1.23
Sand @ Mouth	1.27	.94	.41	.37

The differences between this simulation and the unattended outlets is the significant improvement in the winter low flow and slight reduction in the summer low flows. The satisfaction of the streamflow criteria on the lake outflow channels causes this improvement.

The relationship between regulated and natural annual flows to Saskatchewan indicates that the 50% apportionment requirement on the Beaver River is satisfied. In 1969, the Cold River conveys 67% of the natural flow to Saskatchewan. A comparison of the critical years, i.e. when the ratio between regulated and natural flow is a minimum, follows;

CRITICAL ANNUAL FLOW

(dam^3)

	Natural	Regulated	Reg/Nat
Beaver River	233,700	218,800	0.94
Cold River	304,500	203,200	0.67

The system simulation demonstrates that the maximum annual withdrawals from certain lakes with fully controlled outlets results in;

- low, winter flows in Beaver
- improvement of water quality flows
- general satisfaction of apportionment with Saskatchewan

SECTION 5

SAND RIVER RESERVOIR

5. SAND RIVER RESERVOIR

5.1 GENERAL

The satisfaction of all industrial withdrawals from a single source within the Beaver River Basin was considered as one planning alternative. This scheme reduces the social and environmental impacts to a confined area and reduces the effort required to monitor and manage the water supply in the whole basin. Since the Sand River, on a long term basis, contributes half of the Beaver River flow at the border, its selection as the potential water source is logical. A reservoir was assumed to be located on the Sand River downstream of the confluence with the Wolf River since a potential site was identified in the NE 33 65 R8 W3. The stage/storage curve for this potential reservoir is provided in Appendix B.

5.2 OPERATING CRITERIA

Since the required storage capacity of a reservoir is dependent on the magnitude of the withdrawal and the timing and volume of downstream releases, three sets of operating criteria were simulated to determine the corresponding reservoir size. The withdrawals in all simulations were assumed to be 110,000 dam^3 per annum.

Criteria 1

These criteria are designed to provide a simple operating procedure which ensures satisfaction of the industrial withdrawal and the absolute minimum release. When the reservoir goes below a fixed elevation only the industrial requirement and the absolute minimum outflow are provided. The specific rules are;

- 50,000 dam^3 live storage is reserved to meet the natural absolute minimum flow and the withdrawal
- storage above 50,000 dam^3 live storage is used to regulate and augment the downstream flows to satisfy the streamflow criteria

The reserve of 50,000 dam^3 was calculated to provide the necessary withdrawal and minimum flow over a two year, sustained dry period.

Criteria 2

Criteria 2 attempts to provide the same distribution of low flows up to the PMF values, as the natural situation in the Sand River downstream of the reservoir. The releases from the reservoir are not permitted to exceed the PMF's except when the reservoir is full. The higher flows are therefore stored and used for the industrial withdrawal. The reservoir operating rules are;

- inflow into the reservoir is released downstream if it is less than the PMF
- if inflow is greater than the PMF, the flow above the PMF will be directed into the reservoir up to the full supply level
- no release is made from the reservoir to augment the downstream flows above the PMF values.

Criteria 3

Criteria 3 is a downstream enhancement mode where all low flows below the PMF are augmented to the PMF values and the withdrawal is satisfied. The rule is;

- meet the withdrawal demand and downstream PMF , 100% of the time.

In addition to the above criteria, the general criteria regarding withdrawal deficit and achievement of downstream PMF's were also applied.

5.3 SIMULATION RESULTS

Criteria 1

A summary of the simulation results is presented in Table 5.3.1. The reservoir size was determined to be 130,000 dam^3 of live storage with a maximum depth of 19.7m. All flows are above the minimum natural flow. The number of time periods in which the PMF's were equalled or exceeded has been improved by 15 to 20% over the natural condition. This implies that the low flows have been

Table 5.3.1

POTENTIAL RESERVOIR ON SAND RIVER
SIMULATION SUMMARY

Criteria #1
Maximum Annual Withdrawal - 110,000 cu dam

LAKE LEVELS (m)	REGULATED Annual	Winter	Summer
Maximum	578.60	578.60	578.60
10% Exceedance	578.60	578.60	578.60
Median	576.54	576.42	576.63
90% Exceedance	569.39	568.90	569.88
Minimum	563.88	563.96	563.88

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural			Regulated		
April	8.02	53	...		77	...	
May	10.28	76	:		88	:	
June	6.94	75	:	74	89	:	89
July	4.52	78	:		92	:	
August	4.48	78	:		92	:	
September	3.19	84	..:		95	..:	
October	4.15	81	...		94	...	
November	5.11	59	:		91	:	
December	3.25	55	:	59	85	:	85
January	2.19	55	:		84	:	
February	1.82	54	:		79	:	
March	1.70	51	..:		76	..:	

Average Annual Change in PMF Achievement +20%

	Natural	Regulated
Absolute Minimum (cms)	0.20	0.20
Absolute Maximum (cms)	250.60	247.00

DEFICITS

Mean Annual	112.4 cu dam
Withdrawal	0.1 %
Duration, Deficit > 10%	4 weeks
Duration, Deficit > 30%	2 weeks

improved but during a prolonged dry spell such as 1967-1968, the release from the reservoir is only the absolute minimum.

Criteria 2

The tabulated simulation results are presented in Table 5.3.2. A live storage of 177,000 dam^3 was required in the reservoir. This capacity corresponds to a maximum depth of 21.9m. The achievement of PMF's is identical to the natural situation but less than the simulation with Criteria 1. The reservoir is about 40% larger than that required for Criteria 1. The difference results from the operating policy, particularly in the critical dry period. Criteria 1 permits the reservoir to release only the minimum absolute flow whereas the reservoir must release a flow equal to the inflow to satisfy Criteria 2. Additional storage is therefore required to provide the industrial withdrawal during the critical dry period.

Criteria 3

A live storage of 303,000 dam^3 is required to satisfy the industrial withdrawal and provide donwstream flows equal to the PMF values, 100% of the time. This storage corresponds to a maximum depth of 26.8m. A summary of the simulation results is presented in Table 5.3.3.

The large amount of storage in this reservoir is required to enhance the downstream flows.

5.4 SUMMARY

A reservoir on the Sand River downstream of the confluence with the Wolf, can supply an industrial withdrawal of 110,000 dam^3 per annum. The storage capacity of the reservoir depends on the choice of operating criteria as they relate to downstream flows. A reservoir with a storage capacity of 177,000 dam^3 will maintain the status quo for low flows. A lesser storage of 130,000 dams can improve low flows in most years, but in critically dry periods, the low flows will be severely degraded relative to the natural condition. A large storage capacity of 303,000

Table 5.3.2

POTENTIAL RESERVOIR ON SAND RIVER
SIMULATION SUMMARY

Criteria #2
Maximum Annual Withdrawal - 110,000 cu dam

LAKE LEVELS (m)	REGULATED Annual	 Winter	 Summer
Maximum	580.77	580.77	580.77
10% Exceedance	580.77	580.77	580.77
Median	579.86	579.71	580.03
90% Exceedance	574.66	575.43	574.22
Minimum	563.88	563.88	563.88

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		 Regulated	
April	8.02	53 ...		53 ...	
May	10.28	76 :		76 :	
June	6.94	75 :	74	75 :	74
July	4.52	78 :		78 :	
August	4.48	78 :		78 :	
September	3.19	84 ..:		84 ..:	
October	4.15	81 ...		81 ...	
November	5.11	59 :		59 :	
December	3.25	55 :	59	55 :	59
January	2.19	55 :		55 :	
February	1.82	54 :		54 :	
March	1.70	51 ..:		51 ..:	

Average Annual Change in PMF Achievement 0%

	Natural	Regulated
Absolute Minimum (cms)	0.20	0.20
Absolute Maximum (cms)	250.60	246.90

DEFICITS

Mean Annual	486.4 cu dam
Withdrawal	0.4 %
Duration, Deficit > 10%	6 weeks
Duration, Deficit > 30%	6 weeks

Table 5.3.3

POTENTIAL RESERVOIR ON SAND RIVER
SIMULATION SUMMARY

Criteria #3
Maximum Annual Withdrawal - 110,000 cu dam

LAKE LEVELS (m)	REGULATED		
	Annual	Winter	Summer
Maximum	585.73	585.73	585.73
10% Exceedance	585.73	585.73	585.73
Median	584.52	584.47	584.59
90% Exceedance	578.55	578.48	578.90
Minimum	563.88	565.20	563.88

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED					
		Natural			Regulated		
April	8.02	53	...		100	...	
May	10.28	76	:		100	:	
June	6.94	75	:	74	100	:	100
July	4.52	78	:		100	:	
August	4.48	78	:		100	:	
September	3.19	84	..:		100	..:	
October	4.15	81	...		100	...	
November	5.11	59	:		100	:	
December	3.25	55	:	59	100	:	100
January	2.19	55	:		100	:	
February	1.82	54	:		100	:	
March	1.70	51	..:		100	..:	

Average Annual Change in PMF Achievement +34%

	Natural	Regulated
Absolute Minimum (cms)	0.20	1.70
Absolute Maximum (cms)	250.60	246.90

DEFICITS

Mean Annual	6.4 cu dam
Withdrawal	0.0 %
Duration, Deficit > 10%	0 weeks
Duration, Deficit > 30%	0 weeks

dam^3 will permit significant enhancement of low flows.

The variations in water levels and downstream flows for the full simulation period for all three operating criteria are graphed in Plate 5.4.

The analysis of a potential reservoir on the Sand River, described in this section were exploratory in purpose. The feasibility of a single source for industrial withdrawals and the effects of various operating criteria was determined. This information was used to formulate the regional management alternatives described in the next section.

SECTION 6

REGIONAL MANAGEMENT ALTERNATIVES

6. REGIONAL MANAGEMENT ALTERNATIVES

6.1 INTRODUCTION

The regional management alternatives were developed by Planning Division staff after consideration of the sub-basin analyses, a potential reservoir on the Sand River, and the possibility of pipelining water from the North Saskatchewan. The growth in the demand for water as heavy oil plants were built was also considered. The apportionment requirements on the Beaver and Cold Rivers were 50% and 68% respectively of the annual natural flow. The results were a series of management alternatives geared to satisfying the short term, intermediate term and long term demand for water. Alternatives designed for the period 1985 to 1990 were called short term. The intermediate term was considered to be up to the year 2000. Long term was defined as, up to the year 2015. The intermediate and long term alternatives were categorized as;

- Local Supply - withdraw water from the nearest, feasible source within the Region
- Sand River Reservoir - use a reservoir on the Sand to supplement water supply and regulate the Beaver River to enhance the low flow conditions in the Beaver and the Sand
- Import Water - pipeline water from another basin to supplement the supply in the Beaver River-Cold Lake Region

The short term alternative is essentially one using local supply.

Each alternative was simulated using the water balance model and summary sheets and graphical displays of lake levels and outflows were prepared for each lake affected and all reaches. A description of each simulation and an overall summary of the results are presented in this section.

6.2 SHORT TERM ALTERNATIVE

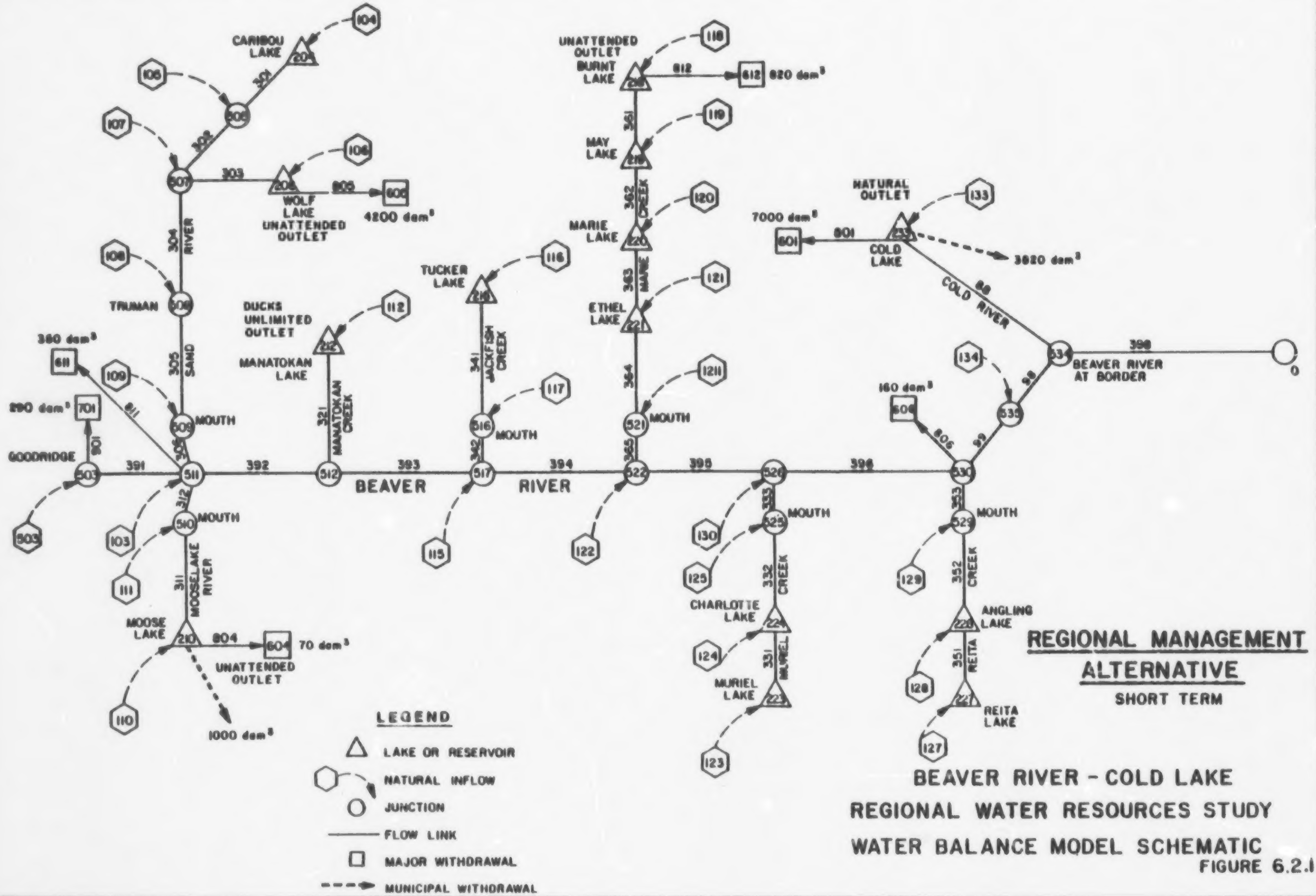
The short term management alternative used local supply with minimal regulation. Wolf, Burnt, and Moose Lakes were simulated with unattended outlets, and Manatokan Lake with the Ducks Unlimited outlet. The remaining lakes were simulated with their existing outlets. Figure 6.2.1 displays the location and magnitude of the short term, annual withdrawals and the regulation conditions of the affected lakes. All withdrawals are less than maximum values determined for the type of outlet in the sub-basin analyses. The lesser withdrawals will result in somewhat higher water levels and outflows for the affected lakes.

The simulation of the short-term management alternative indicated;

- all withdrawals were satisfied in accordance with the deficit criteria
- the apportionment requirements on the Beaver and Cold Rivers were met
- the flows of the Beaver below Reita Creek and the Sand at its mouth were similar to the natural conditions; see Tables 6.2.1 and 6.2.2
- the effects of the municipal and industrial withdrawal on Cold Lake and its outflow were minimal. The lake, at its minimum level is 1 cm below the natural condition and the achievement time for PMF is reduced by 2%. The absolute minimum monthly flows were reduced by 5 to 10%.

The flows in the Beaver near the border and the Sand at the mouth have been graphically compared to the natural flow in Plate 6.2.

In summary, this management alternative can satisfy the anticipated withdrawals without violating the streamflow criteria, and, except for maximum levels, the lake level criteria. The deficit criteria are satisfied except for the small industrial withdrawal on Moose Lake.


CARIBOU LAKE
204
104
106
505
301
302
107
507
303
206
108
805
606
WOLF LAKE
UNATTENDED OUTLET
4200 dam³
304
RIVER
TRUMAN
508
108
305
SAND
109
509
MOUTH
306
380 dam³
611
811
290 dam³
701
901
GOODRIDGE
503
391
511
503
103
312
510
MOUTH
111
311
MOOSELAKE RIVER
MOOSE LAKE
210
804
604
70 dam³
UNATTENDED OUTLET
110
1000 dam³
DUCKS UNLIMITED OUTLET
112
212
MANATOKAN LAKE
321
MANATOKAN CREEK
392
512
393
BEAVER
TUCKER LAKE
116
216
341
JACKFISH CREEK
117
516
MOUTH
342
517
115
394
RIVER
UNATTENDED OUTLET
BURNT LAKE
118
218
812
612
820 dam³
361
MAY LAKE
119
219
362
CREEK
MARIE LAKE
120
220
363
MARIE
ETHEL LAKE
121
221
364
1211
521
MOUTH
365
522
122
395
526
130
333
525
MOUTH
125
332
CREEK
CHARLOTTE LAKE
224
124
331
MURIEL
MURIEL LAKE
223
123
396
530
353
529
MOUTH
129
352
CREEK
ANGLING LAKE
228
128
351
REITA
227
REITA LAKE
127
160 dam³
606
806
99
535
134
98
NATURAL OUTLET
133
235
COLD LAKE
801
601
7000 dam³
3820 dam³
88
COLD RIVER
534
BEAVER RIVER AT BORDER
398
0
LEGEND
LAKE OR RESERVOIR
NATURAL INFLOW
JUNCTION
FLOW LINK
MAJOR WITHDRAWAL
MUNICIPAL WITHDRAWAL

REGIONAL MANAGEMENT ALTERNATIVE

SHORT TERM

BEAVER RIVER - COLD LAKE

REGIONAL WATER RESOURCES STUDY

WATER BALANCE MODEL SCHEMATIC

FIGURE 6.2.1

Table 6.2.1

SYSTEM SIMULATION

Regional Management Alternative
Short Term

BEAVER RIVER d/s REITA CREEK

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED			
		Natural		Regulated	
April	23.40	57		56	
May	23.00	78		79	
June	18.80	71	73	69	73
July	10.60	78		78	
August	10.00	75		76	
September	8.03	79		79	
October	9.10	79		80	
November	10.20	56		55	
December	6.93	54	60	54	58
January	4.89	59		57	
February	4.43	57		51	
March	4.25	55		49	

Average Annual Change in PMF Achievement -1%

	Natural	Regulated
Absolute Minimum (cms)	0.22	0.18
Absolute Maximum (cms)	512.	528.

Table 6.2.2

SYSTEM SIMULATION

Regional Management Alternative
Short Term

SAND RIVER @ MOUTH

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	8.74	56		55	
May	12.60	77		76	
June	8.65	75	74	76	75
July	5.29	78		80	
August	5.20	76		79	
September	3.79	81		84	
October	4.75	79		81	
November	5.73	58		60	
December	3.59	56	62	58	63
January	2.29	58		62	
February	1.78	62		63	
March	1.92	59		55	

Average Annual Change in PMF Achievement +1%

	Natural	Regulated
Absolute Minimum (cms)	0.17	0.16
Absolute Maximum (cms)	272.	280.

6.3 INTERMEDIATE TERM ALTERNATIVES

6.3.1 LOCAL SUPPLY

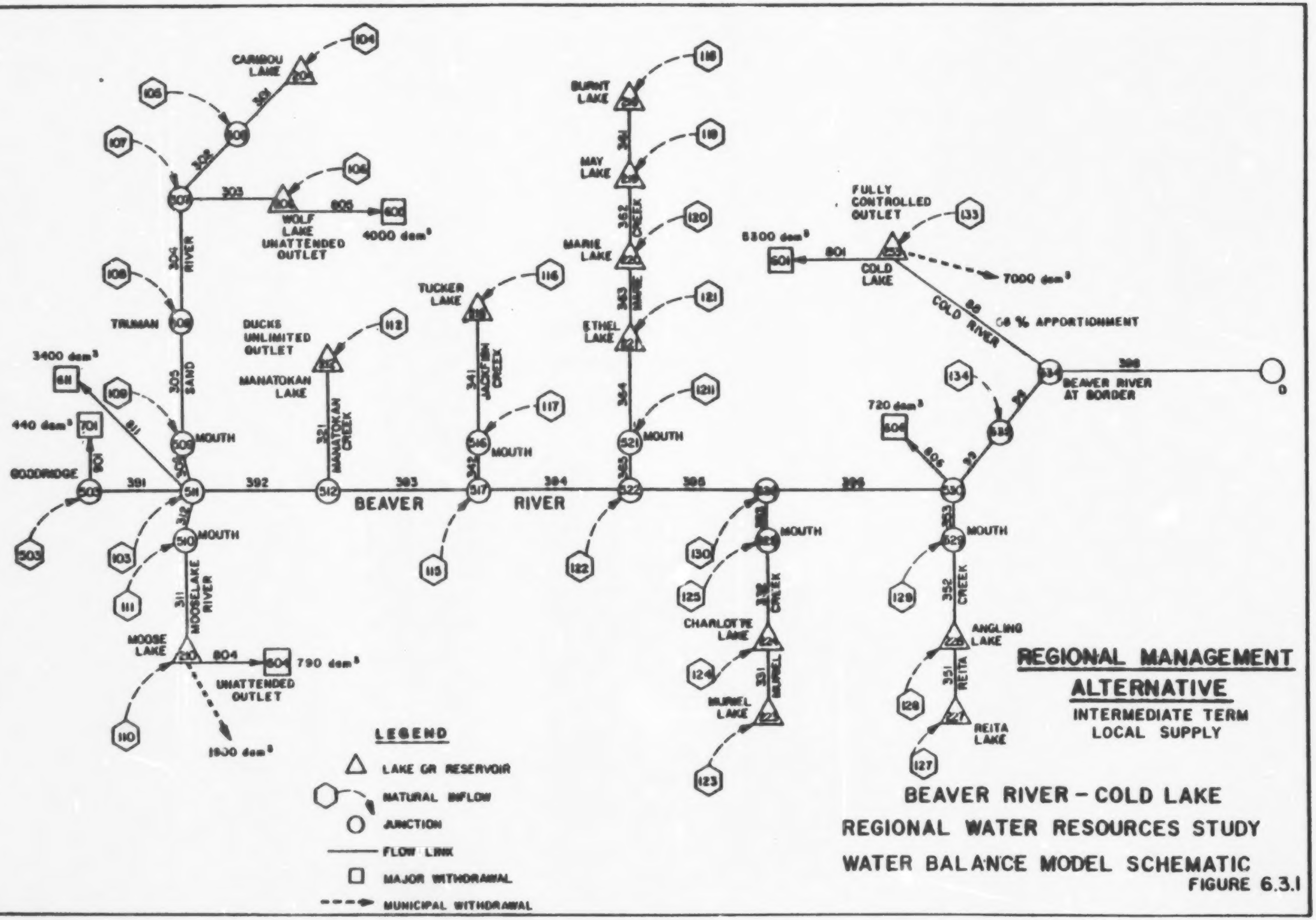
The local supply alternative for the intermediate term is similar to the short term in that the major withdrawals were taken from Cold and Wolf Lakes. Moose Lake has an unattended outlet to provide municipal and industrial water supply. The regulation and withdrawal scheme for the basin is displayed in Figure 6.3.1. The withdrawals are less than the maximum values for the method of regulation used in the sub-basin analyses.

The effects of this alternative on the flows on the Sand and Beaver Rivers are summarized in Tables 6.3.1.1 and 6.3.1.2. The other results are;

- All withdrawals are within the deficit criteria
- apportionment requirements on the Beaver and Cold Rivers were met
- the fully controlled outlet in Cold Lake satisfied the lake level criteria but the low flows were not improved as much as the original +10% streamflow criteria required.
- the low flows in the Beaver are significantly reduced by the withdrawals directly from the river but the streamflow criteria are satisfied
- the Sand River at its mouth is not significantly affected by the withdrawals from Wolf Lake

Plate 6.3 illustrates the variation in flows in the Beaver near the border and the Sand at its mouth. All the intermediate term, management alternatives are compared to the natural condition in the graphs.

From a hydrologic perspective, the local supply alternative satisfies most of the operating criteria but low flows in the Beaver are of concern.


CARIBOU LAKE
104
105
107
301
302
303
304 RIVER
305 SAND
306
WOLF LAKE UNATTENDED OUTLET
106
805
4000 dam³
108
TRUMAN
109
MOUTH
3400 dam³
611
811
440 dam³
701
901
GOODRIDGE
391
392
393
394
395
396
398
BEAVER
RIVER
503
103
111
312
MOUTH
311 MOOSELAKE RIVER
MOOSE LAKE
210
804
790 dam³
UNATTENDED OUTLET
110
1930 dam³
DUCKS UNLIMITED OUTLET
MANATOKAN LAKE
112
321 MANATOKAN CREEK
512
TUCKER LAKE
116
341 JACKFISH CREEK
117
MOUTH
342
517
115
BURNT LAKE
118
361
MAY LAKE
119
362 CREEK
MARIE LAKE
120
363 MARIE
ETHEL LAKE
121
364
1211
MOUTH
521
365
522
122
130
125
MOUTH
CREEK
CHARLOTTE LAKE
124
331 MURIEL
MURIEL LAKE
123
FULLY CONTROLLED OUTLET
133
5300 dam³
601
801
COLD LAKE
7000 dam³
COLD RIVER
68 % APPORTIONMENT
134
534
BEAVER RIVER AT BORDER
D
720 dam³
606
806
535
530
353
MOUTH
529
129
352 CREEK
ANGLING LAKE
128
351 REITA
REITA LAKE
127
LEGEND
LAKE OR RESERVOIR
NATURAL INFLOW
JUNCTION
FLOW LINK
MAJOR WITHDRAWAL
MUNICIPAL WITHDRAWAL

REGIONAL MANAGEMENT ALTERNATIVE
INTERMEDIATE TERM
LOCAL SUPPLY

BEAVER RIVER - COLD LAKE
REGIONAL WATER RESOURCES STUDY
WATER BALANCE MODEL SCHEMATIC
FIGURE 6.3.1

Table 6.3.1.1

SYSTEM SIMULATION

Regional Management Alternative
Intermediate Term - Local Supply

BEAVER RIVER d/s REITA CREEK

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		% OF TIME PMF EXCEEDED Regulated	
April	23.40	57		56	
May	23.00	78		79	
June	18.80	71	73	69	73
July	10.60	78		78	
August	10.00	75		75	
September	8.03	79		78	
October	9.10	79		79	
November	10.20	56		53	
December	6.93	54	60	53	57
January	4.89	59		56	
February	4.43	57		50	
March	4.25	55		47	

Average Annual Change in PMF Achievement -2%

	Natural	Regulated
Absolute Minimum (cms)	0.22	0.07
Absolute Maximum (cms)	512.	527.

Table 6.3.1.2

SYSTEM SIMULATION

Regional Management Alternative
Intermediate Term - Local Supply

SAND RIVER @ MOUTH

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural			Regulated		
April	8.74	56	...		55	...	
May	12.60	77	:		76	:	
June	8.65	75	:	74	76	:	75
July	5.29	78	:		80	:	
August	5.20	76	:		79	:	
September	3.79	81	..:		84	..:	
October	4.75	79	...		82	...	
November	5.73	58	:		60	:	
December	3.59	56	:	62	58	:	64
January	2.29	58	:		63	:	
February	1.78	62	:		63	:	
March	1.92	59	..:		55	..:	
Average Annual Change in PMF Achievement				+2%			
Absolute Minimum (cms)		0.17			0.16		
Absolute Maximum (cms)		272.			280.		

6.3.2 SAND RIVER RESERVOIR

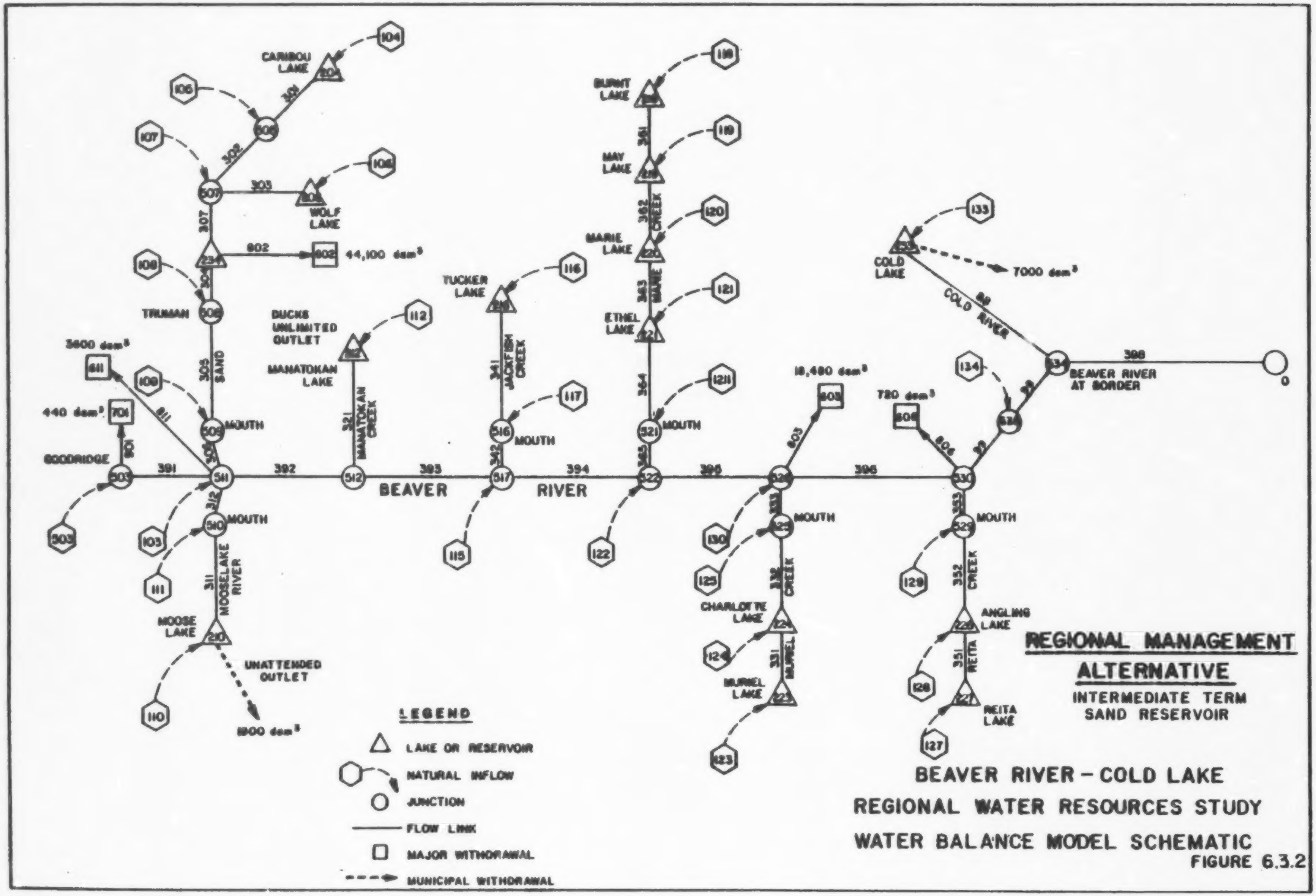
The use of a potential reservoir on the Sand River was analyzed for supply of water to intermediate industrial development. Some industrial uses were considered to withdraw water directly from the reservoir. The flow in the Beaver River was also augmented to permit withdrawals without reducing low flows. The operating criteria for the reservoir were;

- augment the flows in the Sand River such that the PMF values are satisfied 100% of the time
- augment flows in the Beaver River such that all withdrawals can be made and the PMF values of the Beaver at the border will be achieved the same percentage of time as in the natural condition
- provide a constant withdrawal of 1.4 m^3/s (44,200 dam^{-3} per annum) within the deficit criteria

The reservoir capacity to satisfy these criteria was 250,000 dam^3 live storage. The system configuration for this management alternative is displayed in Figure 6.3.2. It will be noted that only municipal withdrawals are made from the lakes and all industrial withdrawals are made from the Sand Reservoir or the Beaver River.

A summary of the results of this simulation as they pertain to the flows in the Beaver and Sand Rivers is presented in Tables 6.3.2.1 and 6.3.2.2. Other results are;

- apportionment is satisfied
- Cold Lake levels and outflows are not significantly changed by the municipal withdrawal of 7000 dam^3 per annum
- Moose Lake levels are improved from their natural condition but the PMF's are somewhat degraded


CARIBOU LAKE
104
106
301
505
107
302
507
303
105
WOLF LAKE
307
802
602
44,100 dam³
234
108
304
TRUMAN
506
DUCKS UNLIMITED OUTLET
112
MANATOKAN LAKE
3600 dam³
611
305
SAND
109
611
440 dam³
701
901
MOUTH
509
321
MANATOKAN CREEK
GOODRIDGE
503
391
306
511
392
512
BEAVER
393
312
MOUTH
510
503
103
111
311
MOOSELAKE RIVER
MOOSE LAKE
210
UNATTENDED OUTLET
110
1900 dam³
TUCKER LAKE
116
341
JACKFISH CREEK
117
516
MOUTH
342
517
394
RIVER
115
BURNT LAKE
118
361
MAY LAKE
119
362
CREEK
120
MARIE LAKE
220
363
MARIE
121
ETHEL LAKE
221
364
1211
521
MOUTH
365
522
122
395
18,480 dam³
803
130
MOUTH
125
CREEK
CHARLOTTE LAKE
124
124
331
MURIEL
MURIEL LAKE
123
396
133
COLD LAKE
7000 dam³
COLD RIVER
398
0
134
534
BEAVER RIVER AT BORDER
780 dam³
806
530
353
MOUTH
529
129
352
CREEK
ANGLING LAKE
351
REITA
128
221
REITA LAKE
127
LEGEND
LAKE OR RESERVOIR
NATURAL INFLOW
JUNCTION
FLOW LINK
MAJOR WITHDRAWAL
MUNICIPAL WITHDRAWAL

REGIONAL MANAGEMENT ALTERNATIVE

INTERMEDIATE TERM
SAND RESERVOIR

BEAVER RIVER - COLD LAKE
REGIONAL WATER RESOURCES STUDY
WATER BALANCE MODEL SCHEMATIC
FIGURE 6.3.2

Table 6.3.2.1

SYSTEM SIMULATION

Regional Management Alternative
Intermediate Term - Sand Reservoir

BEAVER RIVER d/s REITA CREEK

STREAMFLOWS	PNF (cms)	% OF TIME PNF EXCEEDED					
		Natural			Regulated		
April	23.40	57	...		71	...	
May	23.00	78	:		80	:	
June	18.80	71	:	73	74	:	75
July	10.60	78	:		74	:	
August	10.00	75	:		75	:	
September	8.03	79	..:		75	..:	
October	9.10	79	...		77	...	
November	10.20	56	:		57	:	
December	6.93	54	:	60	54	:	62
January	4.89	59	:		61	:	
February	4.43	57	:		61	:	
March	4.25	55	..:		60	..:	

Average Annual Change in PNF Achievement +2%

Absolute Minimum (cms)	0.22	2.43
Absolute Maximum (cms)	512.	517.

Table 6.3.2.2

SYSTEM SIMULATION

Regional Management Alternative
Intermediate Term - Sand Reservoir

SAND RIVER @ MOUTH

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED			
		Natural		Regulated	
April	8.74	56		99	
May	12.60	77		87	
June	8.65	75	74	99	98
July	5.29	78		100	
August	5.20	76		100	
September	3.79	81		100	
October	4.75	79		100	
November	5.73	58		100	
December	3.59	56	62	100	100
January	2.29	58		100	
February	1.78	62		100	
March	1.92	59		100	

Average Annual Change in PMF Achievement +31%

	Natural	Regulated
Absolute Minimum (cms)	0.17	2.54
Absolute Maximum (cms)	272.	271.

An analysis of the 1 in 10 year, weekly low flow of the Beaver at the border showed an increase to $5.04m^3/s$ from $3.00m^3/s$ in the natural summer condition. The absolute minimum flows in both the Sand and Beaver have been greatly improved. These flows are presented in Plate 6.3 for comparison with other alternatives and the natural situation.

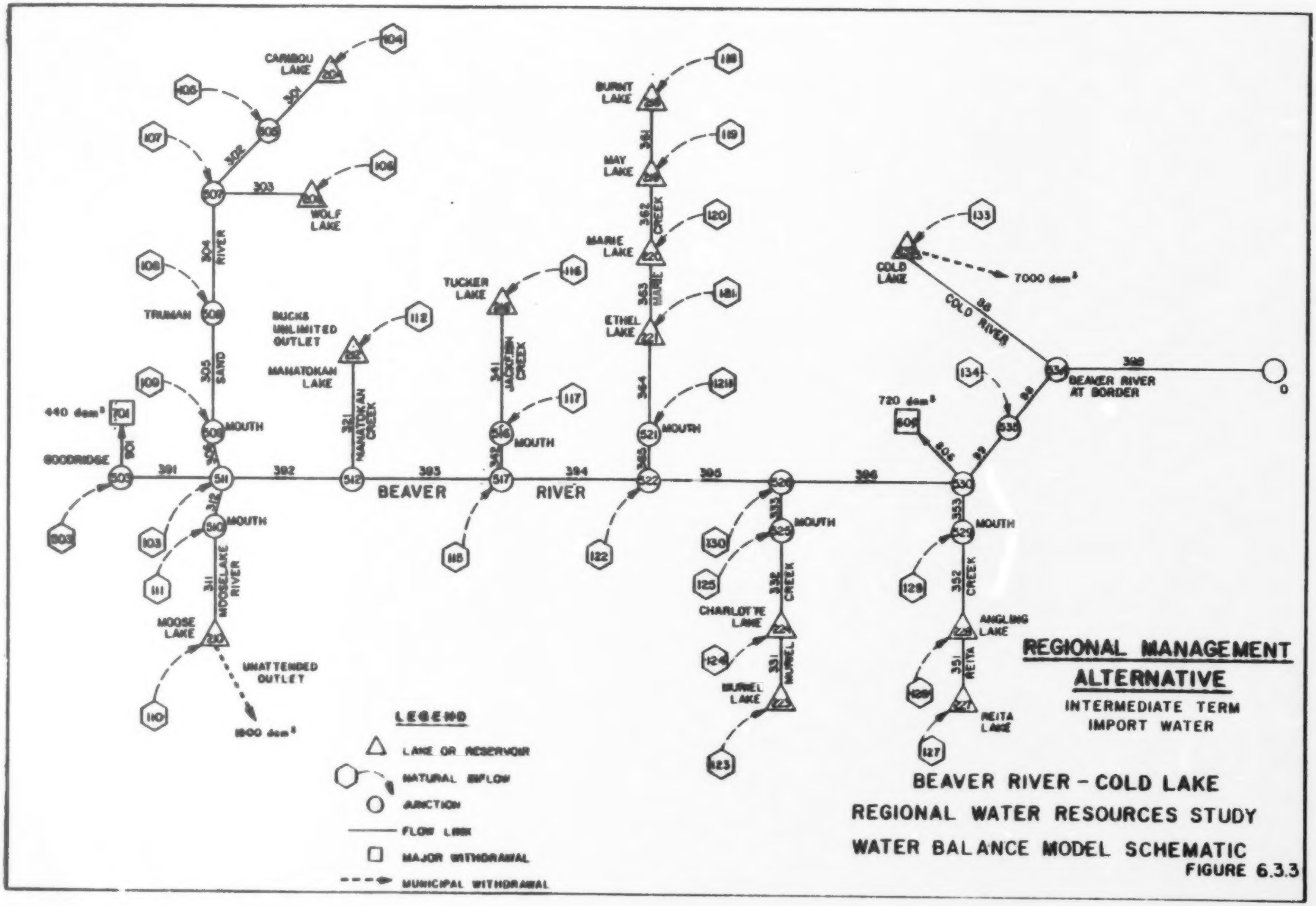
The Sand Reservoir alternative has two benefits; preservation of the natural condition of all lakes except Moose and improvement of low flows in the Beaver and the Sand.

6.3.3 IMPORT WATER

The importation of water from another basin for industrial water supply leaves the Region's lakes to provide municipal water supply and provides maximum available water for instream uses. Figure 6.3.3 also shows a small industrial withdrawal directly from the Beaver River downstream from Reita Creek.

The hydrologic effects on the water resource system of the Region are minimal. Since no withdrawals are made from the Sand River, its flow regime is unchanged from the natural condition. The effects on the Beaver are provided in Table 6.3.3.1. The winter low flows are somewhat reduced, while summer flows are virtually unaffected. Plate 6.3 plots the Beaver flows for this and all other intermediate term alternatives.

The import water alternative leaves the water resource system basically unaffected by industrial withdrawals. The flows in the Beaver and Cold Rivers are somewhat reduced as a result of municipal withdrawals and a minor industrial usage.


CARIBOU LAKE
WOLF LAKE
TRUMAN
GOODRIDGE
440 dam³
701
MOUTH
SAND RIVER
MOOSELAKE RIVER
MOOSE LAKE
UNATTENDED OUTLET
1800 dam³
BUCKS UNLIMITED OUTLET
MANATOKAN LAKE
MANATOKAN CREEK
TUCKER LAKE
JACKFISH CREEK
BURNT LAKE
MAY LAKE
MARIE LAKE
ETHEL LAKE
MARIE CREEK
BEAVER RIVER
CHARLOTTE LAKE
MURIEL LAKE
MURIEL CREEK
ANGLING LAKE
REITA LAKE
REITA CREEK
COLD LAKE
7000 dam³
COLD RIVER
720 dam³
606
BEAVER RIVER AT BORDER
0
LEGEND
LAKE OR RESERVOIR
NATURAL INFLOW
JUNCTION
FLOW LINK
MAJOR WITHDRAWAL
MUNICIPAL WITHDRAWAL

REGIONAL MANAGEMENT ALTERNATIVE

INTERMEDIATE TERM
IMPORT WATER

BEAVER RIVER - COLD LAKE
REGIONAL WATER RESOURCES STUDY
WATER BALANCE MODEL SCHEMATIC
FIGURE 6.3.3

Table 6.3.3.1

SYSTEM SIMULATION

Regional Management Alternative
Intermediate Term - Import Water

BEAVER RIVER d/s REITA CREEK

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED			
		Natural		Regulated	
April	23.40	57	73	56	72
May	23.00	78		79	
June	18.80	71		69	
July	10.60	78		77	
August	10.00	75		73	
September	8.03	79		78	
October	9.10	79	60	78	56
November	10.20	56		52	
December	6.93	54		53	
January	4.89	59		54	
February	4.43	57		51	
March	4.25	55		49	

Average Annual Change in PMF Achievement -2%

	Natural	Regulated
Absolute Minimum (cms)	0.22	0.20
Absolute Maximum (cms)	512.	519.

6.4 LONG TERM ALTERNATIVES

6.4.1 LOCAL SUPPLY

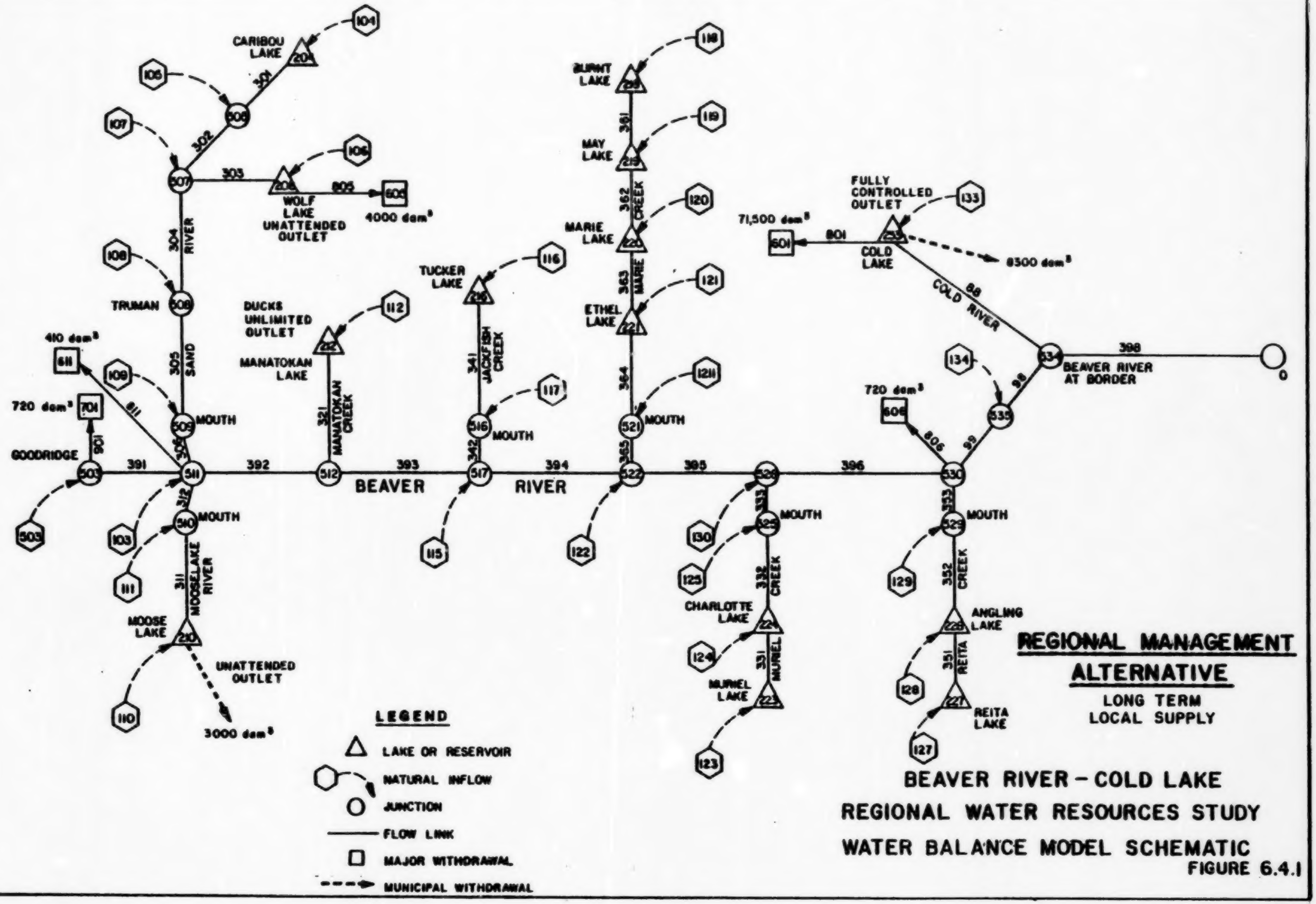
The local supply alternative for the long term places withdrawals on the same lakes as the corresponding intermediate term alternative. A fully controlled outlet was simulated on Cold Lake and the withdrawal increased to 80,000 dam^3 per annum; somewhat higher than allowable according to the sub-basin analysis. Moose Lake provides water for municipal purposes only. The industrial withdrawals directly from the Beaver River have been reduced from the intermediate term scenario. The withdrawal scenario and basin configuration for this alternative are depicted on Figure 6.4.1.

The results of the analyses are;

- apportionment on the Beaver and Cold Rivers is satisfied
- low flows in the Cold River, particularly in winter, are severely degraded. PMF achievement times are 20 to 25% below natural
- regulated Cold Lake levels satisfy the criteria
- Moose Lake acts in an identical manner to the sub-basin simulation
- the effects on the flows in Sand and Beaver Rivers are summarized in Tables 6.4.1.1 and 6.4.1.2. Low flows in the Beaver are reduced slightly.

A comparison between flows in the Sand and Beaver Rivers for all the long term alternatives and the natural flow is made in Plate 6.4.

With reduced withdrawals from the Beaver, the long term, local supply alternative is an improvement over the corresponding intermediate term alternative on the Beaver. Although apportionment is satisfied on the Cold River, the low flow regime has been significantly altered by the relatively large municipal and industrial withdrawal from Cold Lake.


CARIBOU LAKE
WOLF LAKE UNATTENDED OUTLET
4000 dam³
TRUMAN
SAND RIVER
410 dam³
720 dam³
GOODRIDGE
MOUTH
MOOSE LAKE
MOOSELAKE RIVER
UNATTENDED OUTLET
3000 dam³
DUCKS UNLIMITED OUTLET
MANATOKAN LAKE
MANATOKAN CREEK
BEAVER RIVER
TUCKER LAKE
JACKFISH CREEK
BURNT LAKE
MAY LAKE
MARIE LAKE
MARIE CREEK
ETHEL LAKE
CHARLOTTE LAKE
MURIEL LAKE
MURIEL CREEK
FULLY CONTROLLED OUTLET
71,500 dam³
COLD LAKE
8500 dam³
COLD RIVER
720 dam³
BEAVER RIVER AT BORDER
ANGLING LAKE
REITA LAKE
REITA CREEK
LEGEND
LAKE OR RESERVOIR
NATURAL INFLOW
JUNCTION
FLOW LINK
MAJOR WITHDRAWAL
MUNICIPAL WITHDRAWAL

REGIONAL MANAGEMENT ALTERNATIVE

LONG TERM
LOCAL SUPPLY

BEAVER RIVER – COLD LAKE
REGIONAL WATER RESOURCES STUDY
WATER BALANCE MODEL SCHEMATIC
FIGURE 6.4.1

Table 6.4.1.1

SYSTEM SIMULATION

Regional Management Alternative
Long Term - Local Supply

BEAVER RIVER d/s REITH CREEK

STREAMFLOWS	PMF	% OF TIME PMF EXCEEDED			
	(cms)	Natural		Regulated	
April	23.40	57		56	
May	23.00	78		79	
June	18.80	71	73	69	73
July	10.60	78		78	
August	10.00	75		76	
September	8.03	79		79	
October	9.10	79		80	
November	10.20	56		54	
December	6.93	54	60	54	57
January	4.89	59		56	
February	4.43	57		51	
March	4.25	55		48	
Average Annual Change in PMF Achievement				-2%	
Absolute Minimum (cms)		0.22		0.16	
Absolute Maximum (cms)		512.		527.	

Table 6.4.1.2

SYSTEM SIMULATION

Regional Management Alternative
Long Term - Local Supply

SAND RIVER @ MOUTH

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	8.74	56		55	
May	12.60	77		76	
June	8.65	75	74	76	75
July	5.29	78		80	
August	5.20	76		79	
September	3.79	81		84	
October	4.75	79		82	
November	5.73	58		60	
December	3.59	56	62	58	64
January	2.29	58		63	
February	1.78	62		63	
March	1.92	59		55	

Average Annual Change in PMF Achievement +2%

	Natural	Regulated
Absolute Minimum (cms)	0.17	0.16
Absolute Maximum (cms)	272.	280.

6.4.2 SAND RIVER RESERVOIR

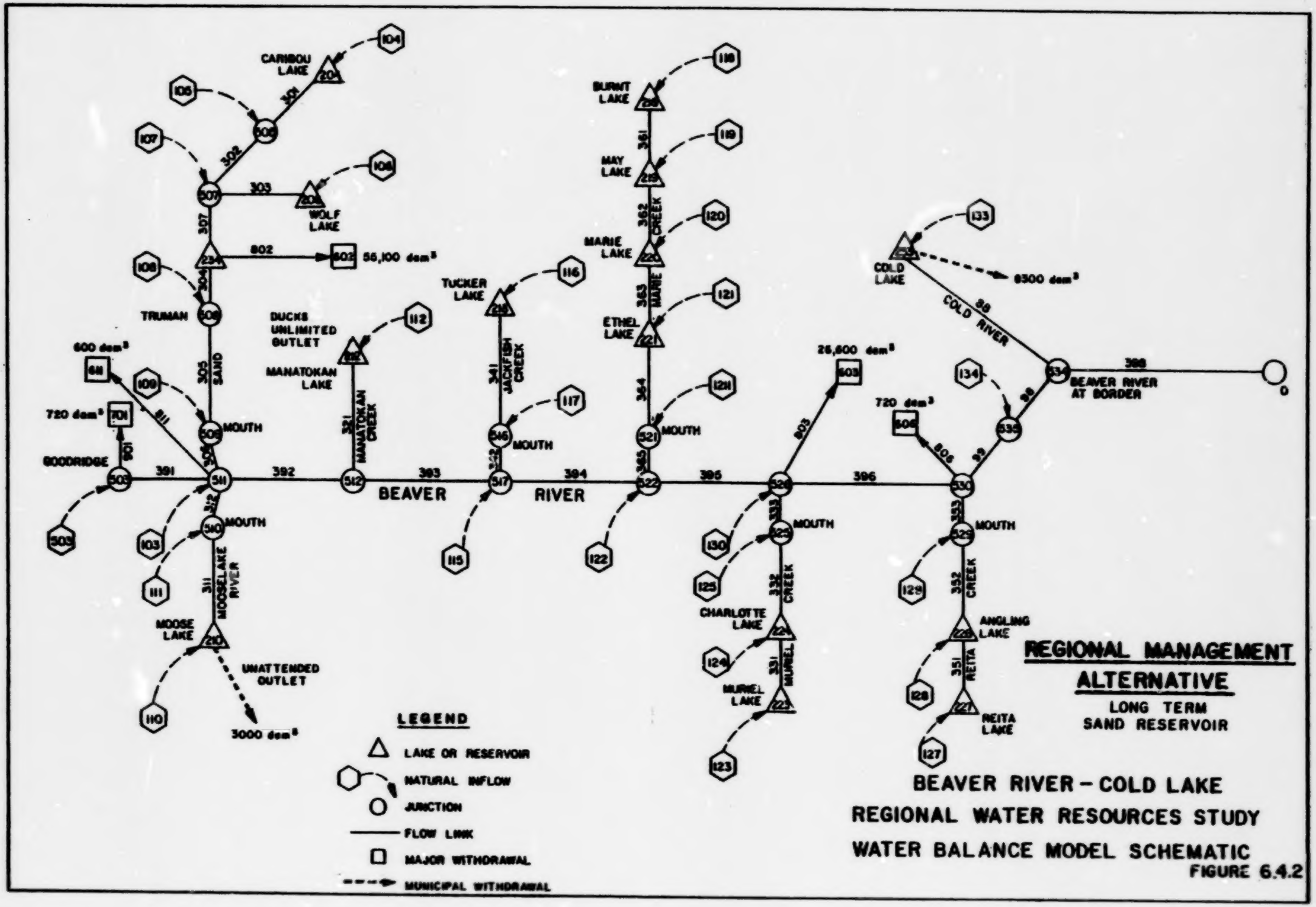
In the long term, the Sand Reservoir served the same purpose as the short term but withdrawals from the reservoir and along the Beaver were increased. The operating criteria for the reservoir were identical to those used in the short term. The withdrawal from the reservoir was increased from $1.4m^3/s$ to $1.75m^3/s$ (55,000 dam^3 per annum). The reservoir capacity to satisfy the criteria was 300,000 dam^3, live storage. The system configuration for this management alternative is displayed in Figure 6.4.2. The withdrawal from the Beaver at its confluence with the Sand has been reduced; all other withdrawals were increased.

Tables 6.4.2.1 and 6.4.2.2 present a summary of the simulation results as they relate to flows in the Beaver and Sand Rivers. Other results are;

- apportionment is satisfied on the Beaver and Cold Rivers
- streamflow criteria are satisfied throughout the region
- Cold Lake levels are not appreciably changed from the natural condition but the achievement level of the PMF's is reduced by 2% as a result of the 8300 dam^3, municipal withdrawal
- Moose Lake levels are acceptable but the outflows do not satisfy the streamflow criteria

The 1 in 10 year weekly low flows and the absolute minimum flows are greatly improved in both the Sand and Beaver Rivers. The summer,weekly low flow in the Beaver at the border was improved from $3.00m^3/s$ to $5.00m^3/s$. These flows are presented in Plate 6.4 for comparison with other alternatives and the natural condition.

The Sand Reservoir alternative permits the preservation of the natural condition of all lakes except Moose and improvement of low flows in the Beaver and Sand Rivers.


CARIBOU LAKE
104
204
301
106
505
302
107
507
303
108
203
WOLF LAKE
307
234
802
602
55,100 dam³
108
304
TRUMAN
506
305
SAND
600 dam³
611
811
109
720 dam³
701
101
GOODRIDGE
503
391
508
MOUTH
306
511
312
510
MOUTH
503
103
111
311
MOOSELAKE RIVER
MOOSE LAKE
210
110
UNATTENDED OUTLET
3000 dam³
DUCKS UNLIMITED OUTLET
112
MANATOKAN LAKE
321
MANATOKAN CREEK
392
512
BEAVER
393
TUCKER LAKE
116
218
341
JACKFISH CREEK
117
516
MOUTH
342
517
RIVER
115
394
BURNT LAKE
118
361
MAY LAKE
119
219
362
CREEK
MARIE LAKE
120
220
363
MARIE
ETHEL LAKE
121
221
364
121I
521
MOUTH
365
522
122
395
526
803
603
26,600 dam³
333
MOUTH
130
525
125
332
CREEK
CHARLOTTE LAKE
224
124
331
MURIEL
MURIEL LAKE
223
123
396
COLD LAKE
133
8300 dam³
89
COLD RIVER
720 dam³
606
806
530
97
535
134
98
534
398
BEAVER RIVER AT BORDER
0
353
529
MOUTH
129
352
CREEK
ANGLING LAKE
226
128
351
REITA
227
REITA LAKE
127
LEGEND
LAKE OR RESERVOIR
NATURAL INFLOW
JUNCTION
FLOW LINK
MAJOR WITHDRAWAL
MUNICIPAL WITHDRAWAL

REGIONAL MANAGEMENT ALTERNATIVE

LONG TERM
SAND RESERVOIR

BEAVER RIVER - COLD LAKE
REGIONAL WATER RESOURCES STUDY
WATER BALANCE MODEL SCHEMATIC
FIGURE 6.4.2

Table 6.4.2.1

SYSTEM SIMULATION

Regional Management Alternative
Long Term - Sand Reservoir

BEAVER RIVER d/s REITA CREEK

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	23.40	57	...	71	...
May	23.00	78	:	80	:
June	18.80	71	: 73	75	: 75
July	10.60	78	:	74	:
August	10.00	75	:	75	:
September	8.03	79	..:	75	..:
October	9.10	79	...	75	...
November	10.20	56	:	58	:
December	6.93	54	: 60	55	: 62
January	4.89	59	:	62	:
February	4.43	57	:	61	:
March	4.25	55	..:	60	..:

Average Annual Change in PMF Achievement +2%

	Natural	Regulated
Absolute Minimum (cms)	0.22	2.46
Absolute Maximum (cms)	512.	516.

Table 6.4.2.2

SYSTEM SIMULATION

Regional Management Alternative
Long Term - Sand Reservoir

SAND RIVER @ MOUTH

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	8.74	56	74	100	98
May	12.60	77		88	
June	8.65	75		100	
July	5.29	78		100	
August	5.20	76		100	
September	3.79	81		100	
October	4.75	79	62	100	100
November	5.73	58		100	
December	3.59	56		100	
January	2.29	58		100	
February	1.78	62		100	
March	1.92	59		100	

Average Annual Change in PMF Achievement +31%

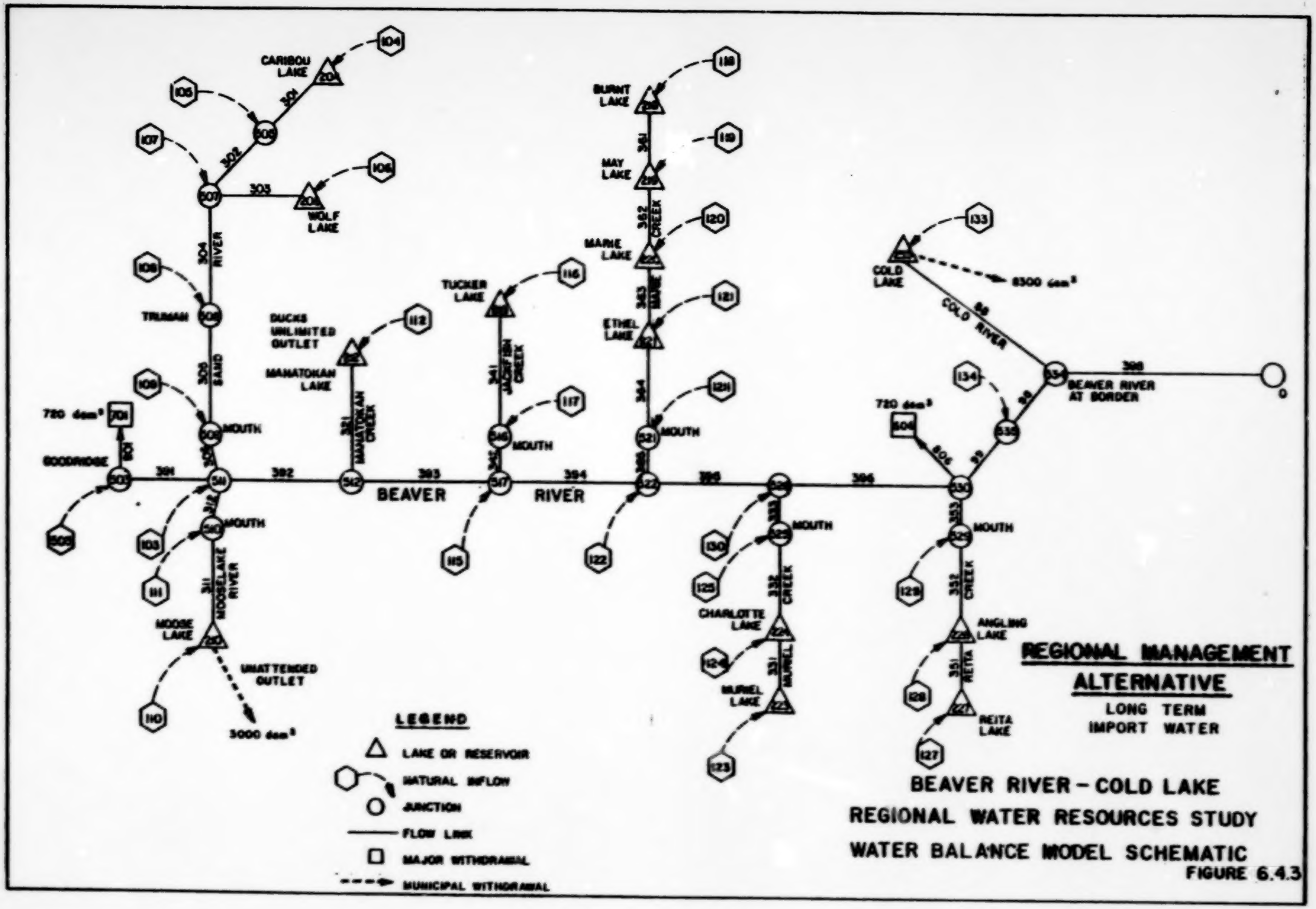
	Natural	Regulated
Absolute Minimum (cms)	0.17	2.75
Absolute Maximum (cms)	272.	271.

6.4.3 IMPORT WATER

The long term alternative of importing water into the Region for industrial purposes is essentially the short term alternative with increased municipal withdrawals from Moose and Cold Lakes. Figure 6.4.3 illustrates the basin configuration and the withdrawals.

The hydrologic effects on the Beaver River are summarized in Table 6.4.3.1. Again the winter low flows are slightly reduced while summer flow are not significantly affected. Apportionment is easily satisfied on the Cold River. Plate 6.4 plots the flows in the Beaver for this and all other long term alternatives.

The import water alternative does not use the water resources of the immediate Region to satisfy the potential industrial demand for water and the water resource system is basically unaffected by the municipal withdrawals and one small industrial usage.


CARIBOU LAKE
WOLF LAKE
TRUMAN
SAND RIVER
MOUTH
GOODRIDGE
720 dam³
701
BEAVER RIVER
DUCKS UNLIMITED OUTLET
MANATOKAN LAKE
MANATOKAN CREEK
TUCKER LAKE
JACKFISH CREEK
BURNT LAKE
MAY LAKE
MARIE LAKE
MARIE CREEK
ETHEL LAKE
MOOSE LAKE
MOOSELAKE RIVER
UNATTENDED OUTLET
3000 dam³
CHARLOTTE LAKE
MURIEL LAKE
MURIEL CREEK
COLD LAKE
8300 dam³
COLD RIVER
BEAVER RIVER AT BORDER
720 dam³
ANGLING LAKE
REITA LAKE
REITA CREEK
LEGEND
LAKE OR RESERVOIR
NATURAL INFLOW
JUNCTION
FLOW LINK
MAJOR WITHDRAWAL
MUNICIPAL WITHDRAWAL

REGIONAL MANAGEMENT ALTERNATIVE

LONG TERM IMPORT WATER

BEAVER RIVER - COLD LAKE REGIONAL WATER RESOURCES STUDY

WATER BALANCE MODEL SCHEMATIC

FIGURE 6.4.3

Table 6.4.3.1

SYSTEM SIMULATION

Regional Management Alternative
Long Term - Import Water

BEAVER RIVER d/s REITA CREEK

STREAMFLOWS	PMF (cms)	% OF TIME PMF EXCEEDED Natural		Regulated	
April	23.40	57		56	
May	23.00	78		79	
June	18.80	71	73	68	72
July	10.60	78		77	
August	10.00	75		73	
September	8.03	79		78	
October	9.10	79		78	
November	10.20	56		52	
December	6.93	54	60	53	56
January	4.89	59		54	
February	4.43	57		50	
March	4.25	55		48	

Average Annual Change in PMF Achievement -2%

	Natural	Regulated
Absolute Minimum (cms)	0.22	0.20
Absolute Maximum (cms)	512.	519.

APPENDIX A

TERMS OF REFERENCE

TERMS OF REFERENCE

B. TERMS OF REFERENCE

The specific terms of reference for the water balance modelling element are set out below. These terms of reference are intended to be consistent with the Study Outline and should be referenced to the Outline.

Meetings and Presentations

(1) The consultant must allow for meetings and a presentation with Alberta Environment during completion of the water balance model element. The consultant must allow for three formal meetings with either the Study Team or a Technical Advisory Committee. These meetings will consist of a pre-study meeting to confirm procedures, an interim meeting to report on preliminary findings and further investigations and a post study meeting to review results. The above meetings will be supplemented by progress report meetings to ensure project review with the Department once every two weeks.
The consultant must also allow for one formal presentation. The presentation will consist of either a presentation to the Department or attendance and participation in a public presentation.

(2) In addition to the above-noted formal meetings and presentation, the consultant is expected to maintain regular liaison with the Department and provide monthly written progress reports on the status of the study.

Background Information Review

(3) Review all pertinent studies, reports, maps and data related to the study areas.

Modelling

(4) Determine the implications of the study objectives, availability of data and the proposed procedures for evaluation and optimization of management alternatives on model development.

(5) Develop a modelling strategy that satisfies the following requirements:

(a) the model must undertake a surface water accounting or balance relating water supply and various water uses under alternative operation procedures.

(b) the model must incorporate water quality directly or be compatible with a special purpose site specific water quality model.

(c) the model must be flexible to allow quick and easy adjustment of the level of detail and the number of physical system components represented.

(d) the model must be designed to be readily transferred for use on other basins.

(6) Submit 10 copies of a letter type report on the modelling strategy, review it with Alberta Environment and adjust as necessary.

(7) Develop performance specifications for the model which describe the model structure; input data and output; physical system elements, processes and water uses to be simulated; and system operating procedures that can be considered.

(8) Submit 10 copies of a letter type report on the preposed performance specifications, review the specifications with

Alberta Environment and revise as necessary.

(9) Develop or adopt an existing water balance model that is consistent with the above performance specifications and any functional specifications necessary to ensure operation on the Government of Alberta computing system.

(10) Prepare a users guide, flow charts and copies of the computer program coding as development proceeds for the review and approval of Alberta Environment.

(11) Test the model on a test basin or a portion of the study area such that all of the model components are utilized; ensure satisfactory operation; test the model to assess its accuracy and present the results in a letter type report for review and approval.

(12) Set up the programs on the Alberta Government computing system for operation on the entire study area, test to ensure satisfactory operation over the hydrologic study period 1955-80 and familiarize representatives of Alberta Environment with the model's operation.

(13) Using priorities for water allocation defined by the penalty point system developed during the water demand component simulate a weekly water balance over the hydrologic period of record 1955-80 for the water demand scenarios forecasted for the years 1985, 2000 and 2015. At least two development scenarios will exist for each future time frame.

Management Alternatives

(14) Using water supply and use management alternatives identified by the Department, simulate a weekly water balance as per item (13) to evaluate the benefits/impacts of the alternatives.

Reports and Documentation

(15) Provide documentation of the computer program(s) in the form of a User's Manual, Programmers Manual and Non-computerized Procedure Manual as described in the report, "Departmental Computing Manual, Model Development Format." A preliminary draft of each manual will be submitted to Alberta Environment for inspection and approval.

Reports and Documentation

(1) The final submission shall consist of the following reports and documentation; a report with technical appendices; map cronaflexes and white prints; and any computer model documentation. Twenty-five copies of a report shall be produced outlining the work program and results. The technical appendices shall detail all data, methodologies and assumptions used in completing

bases used to derive any topographical mapping undertaken for the project will be provided to the Department. Five copies of all computer program documentation are also to be provided. The report, maps and the computer documentation must be clearly cross-referenced. Ten copies of all reports should be submitted in draft for review and approval prior to preparation of final copies.

METHODOLOGY TIMING AND PROJECT TEAM

2.0 Methodology

2.1 Computer Programs

The consultant proposes the adaptation of the water balance model developed for the South Saskatchewan Planning Program to meet the needs of the Cold Lake - Beaver Regional Water Resources Study. This model is comprehensive, and has the sufficient flexibility and modularity to model the physical system represented by the Beaver River Basin. Certain modifications and additions to the computer programs of the existing model will be necessary to meet the terms of reference. These requirements are:

(a) simulation of weekly flows
(b) incorporation of water quality parameters
(c) evaluation of management alternatives

The simulation of weekly flows poses a simulation problem when the time of travel for flow through the model system approaches or is greater than 7 days. Normally, water balance models such as that used on the South Saskatchewan assume that water can flow from any point in the modelled system to any other point within the time interval simulated. This simulation time interval has usually been one month. The Beaver River Basin water balance model, depending on the extent of the physical system that is modelled, may require a special programming feature to simulate the lag in flow between various segments of the system. This feature has been developed, in concept, and can be programmed into the South Saskatchewan water balance model.

The incorporation of water quality into the water balance model can be achieved for conservative pollutants such as sulphates. The extent to which the model can incorporate effluent flows is limited by the insignificance of the effluent flow rates relative to the flows in the receiving streams. Therefore effluent flows will not be simulated but the concentration of one or two conservative contaminants in reaches downstream of the point of effluent discharge can be calculated and incorporated with the simulation results for each time interval.

The water balance model can be made compatible with a special purpose, site specific water quality model by defining the reaches of interest in a constant manner in the two models. In this way, the water balance model could provide weekly flows in the reaches for a more detailed spatial and temporal analysis in the water quality model or the water quality model could be used to determine flow constraints in the corresponding flow links of the water balance model.

The evaluation and optimization of water management alternatives requires a water balance, output summary program. The South Saskatchewan model does not have such a program, although the Oldman water balance model used a statistical program to summarize and analyse the results of the simulation program. A weekly simulation of the Basin over 26 years will produce 1352 data values for each component in the model. The simulation output will comprise approzimately 100 pages making it intractable to comprehensive manual analysis. A post processor is therefore proposed to enable the model users to do a variety of analytic or summary type tasks such as:

- flow duration curves for reaches
- elevation versus time plots for lakes
- total basin withdrawals

- total annual basin runoff
- seasonal or annual water shortages by volume or percent of demand
- contaminant concentration versus time
- annual actual volume to apportionment versus entitlement

2.2 Basin Schematic

To illustrate the nature of the water balance model proposed for the Beaver River Basin a schematic is presented. This schematic is the discretization of the basin as previously developed by the Planning Team and proposed component participants. The schematic depicts the capabilities of the water balance model and indicates the nature of data requirements.

The data requirements of the example schematic provide some insight into the scope of the data gathering and estimation task and are presented here for illustrative purposes:

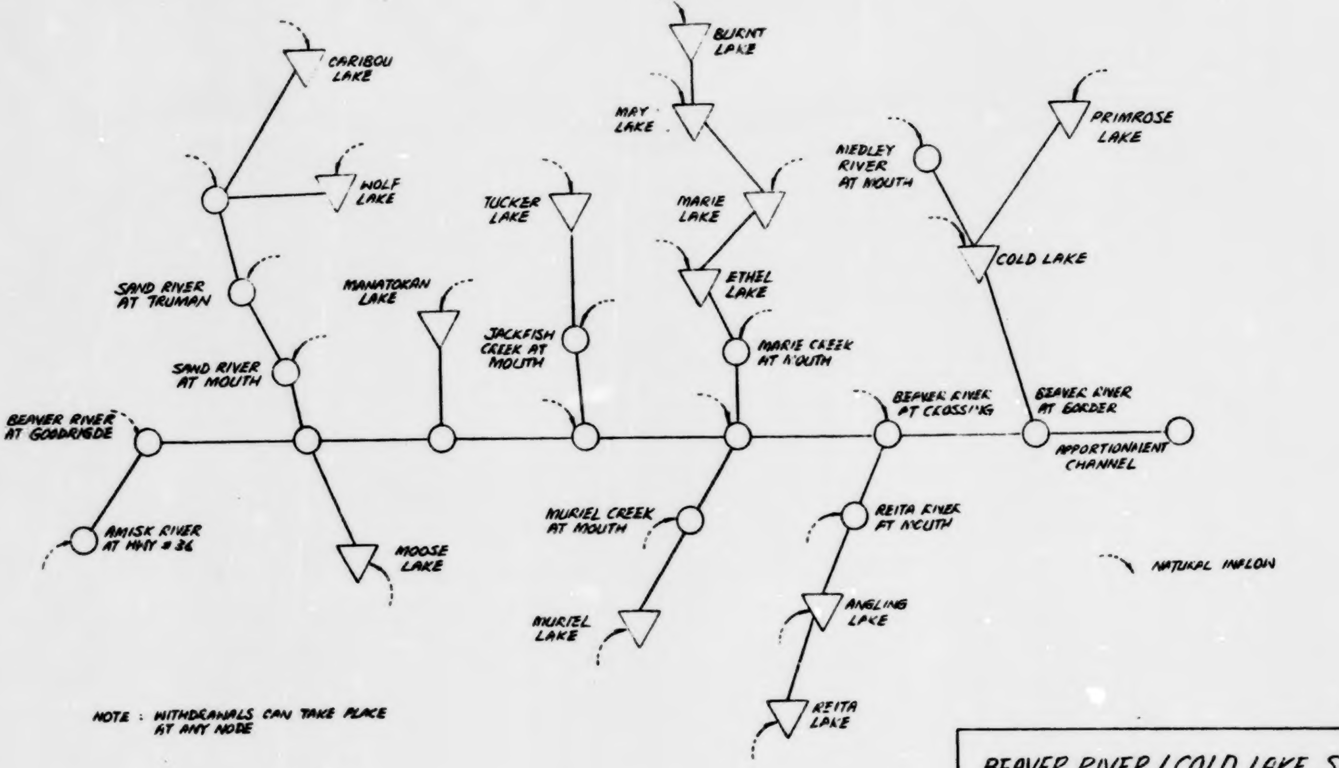
- water supply data on runoff for each major creek, into each major lake, and for the upper Beaver watershed

- location, magnitude and weekly variation of major withdrawals and return flows

- stage/discharge characteristics of the outlets from the major lakes

- stored volume/elevation table for the major lakes

- desirable flow and elevation levels for each



CARIBOU LAKE
WOLF LAKE
SAND RIVER AT TRUMAN
SAND RIVER AT MOUTH
BEAVER RIVER AT GOODRIDGE
AMISK RIVER AT HWY # 36
MOOSE LAKE
MANATOKAN LAKE
TUCKER LAKE
JACKFISH CREEK AT MOUTH
BURNT LAKE
MAY LAKE
MARIE LAKE
ETHEL LAKE
MARIE CREEK AT MOUTH
MURIEL CREEK AT MOUTH
MURIEL LAKE
MEDLEY RIVER AT MOUTH
PRIMROSE LAKE
COLD LAKE
BEAVER RIVER AT CROSSING
BEAVER RIVER AT BORDER
APPORTIONMENT CHANNEL
REITA RIVER AT MOUTH
ANGLING LAKE
REITA LAKE
NATURAL INFLOW

NOTE : WITHDRAWALS CAN TAKE PLACE AT ANY NODE

BEAVER RIVER / COLD LAKE STUDY
WATER BALANCE MODEL SCHEMATIC

simulation time interval in a year, in the river reaches and lakes respectively

- magnitude and location of minor withdrawals

- location and mass discharge of recovery and municipal plant effluent

The water balance model consultant will collect and organize the data for the model by providing other component participants with a general description of the data requirements and format specifications.

3.0 Water Balance Analyses

The water balance model will be used to analyse water demand scenarios forecasted for the years 1985, 2000 and 2015. Each scenario will consider two potential development levels and configurations. This first set of analyses will be conducted using natural flows without incorporating potential water supply or water use management alternatives. These analyses will identify water balance or quality problems requiring the consideration of management alternatives. The use of one set of priorities for water allocation between contending uses is recommended and will result in six simulation runs of the water balance model for the initial analyses. These runs will be made when the water supply and demand data are available and after operating priorities have been established by the Planning Team.

A second series of simulations will be required when the management alternatives have been screened and developed to the point where data can be provided to the model. The number of computer simulations required to evaluate these alternatives is difficult to predetermine but considering there are six development scenarios and assuming there are eight management alternatives all of which are not appropriate to all six development scenarios, an estimated 30 computer simulations can be anticipated for the management alternative evaluation activity.

4.0 Reports and Model Documentation

The consultant recognizes the need for thorough, step by step, reporting on the modelling process as it applies to this study and documentation of the programming tools used to support the process. The use of letter reports improves the efficiency and timeliness. Letter reports will therefore be provided, on modelling strategy, performance specifications for the model and test basin operation. Documentation of the computer programs will include a User's Guide, User's Manual, Programmer's Manual and Non-Computerized Procedure Manual. A final, formal submission on modelling will be prepared to document the modelling activities and summarize the purpose, basin configuration, results and observations from computer simulations.

The modelling strategy is the formal definition of the interaction of models with the planning process. The planning process has several successive stages:

1. problem identification
2. data gathering and estimation
3. problem analysis
4. identification of management alternatives
5. evaluation of management alternatives
6. selection of management policies and schemes

As stated previously, the initial planning stages may be iterative. For instance, the identification of a management alternative may prompt additional data gathering. Models can be used at various stages in the process. The nature of the model and the types of simulations performed will change as the planning program proceeds. The strategy for model use will outline the nature, and purpose of models throughout the program.

Elaboration on the content of the performance specifications and test basin operation reports above that provided in the terms of reference is not required.

Since the adaptation of the water balance model developed for the South Saskatchewan Planning Program is proposed, only modification of the documentation of the computer programs for that model will be required. A User's Guide pertinent to the modified model will be prepared as soon as possible to ensure understanding of the models capabilities and requirements by all participants in the study. Flow charts and computer codes will be provided upon request, as the modifications to the programs are developed.

The final submission for the water balance modelling component will document the data methodology and assumptions in a technical report and will outline the use of water balance model and results in a general report. The results of the computer simulations will be summarized and presented in tabular format for ease of comparison. The description of the use of the model will avoid technical jargon and be understandable to the general public. The consultant will provide the following upon completion of the modelling component

(a) 10 copies of the draft technical report
(b) 10 copies of the draft general report
(c) 5 copies of all program documentation
(d) 15 copies of the final technical report
(e) 25 copies of the final general report

Cronaflexes will be provided as required.

TERMS OF REFERENCE

5.0 Component Logistics

5.1 Staff Committment

The modelling component will be staffed by Mike Thompson and Vincent Chiu, both of which are experienced in the development and use of planning models, in particular, water balance models. Mike will direct and be responsible for this study component and provide 52 man days. Vincent will program the modifications to the South Saskachewan model, set up the data for computer runs, and assist in the analysis of simulations, report writing and documentation. His time committment is 98 man days.

APPENDIX B

DATA FOR MODEL

CONTENTS

1. DOMESTIC, MUNICIPAL & IRRIGATION SURFACE WITHDRAWALS FOR 2015
2. STARTING ELEVATIONS OF LAKES
3. STAGE/STORAGE AND STAGE/DISCHARGE CURVES FOR EXISTING OUTLETS
4. STAGE/STORAGE CURVE FOR POTENTIAL SAND RESERVOIR
5. REVISED COLD LAKE INFLOWS

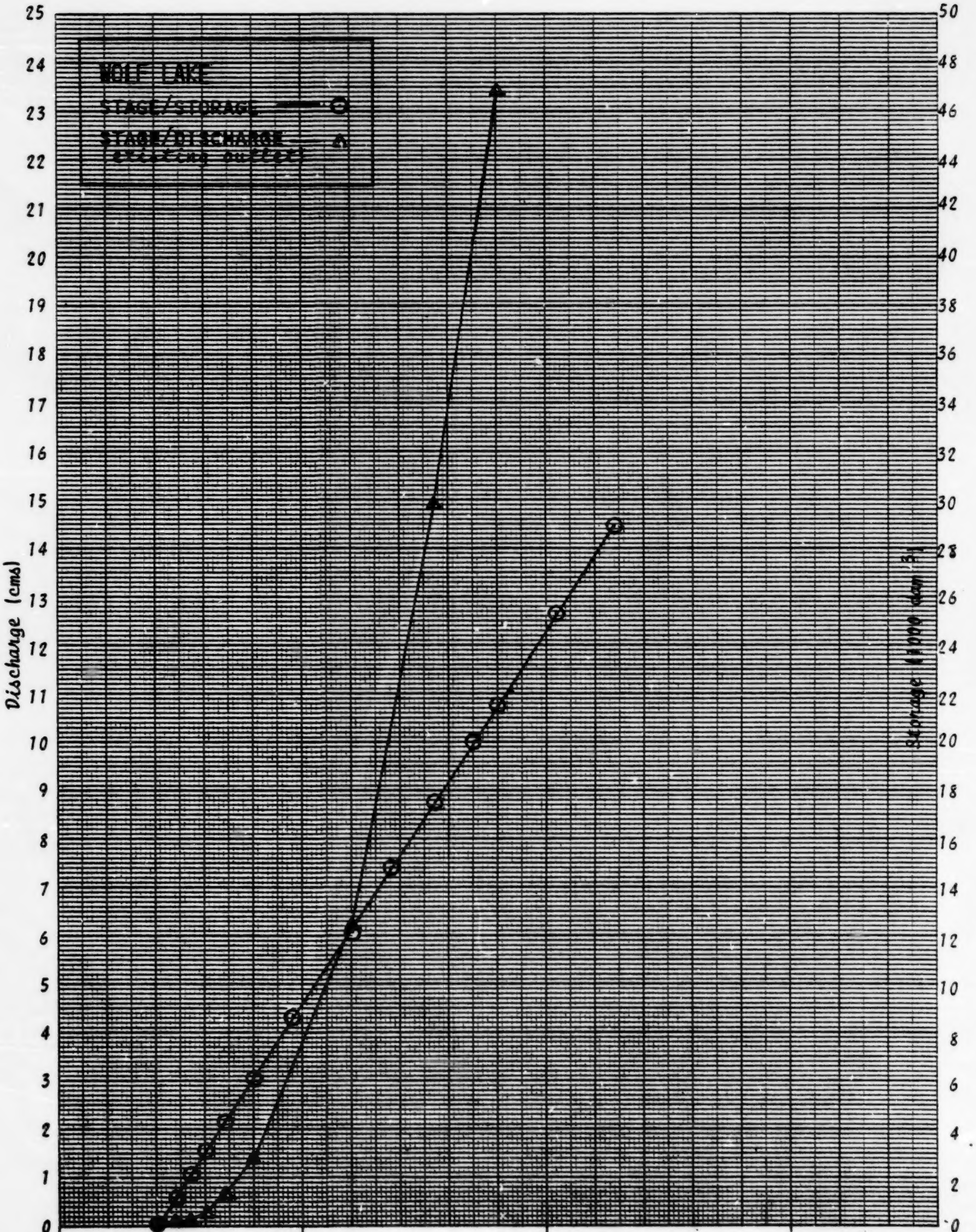
DOMESTIC, MUNICIPAL & IRRIGATION SURFACE WITHDRAWALS

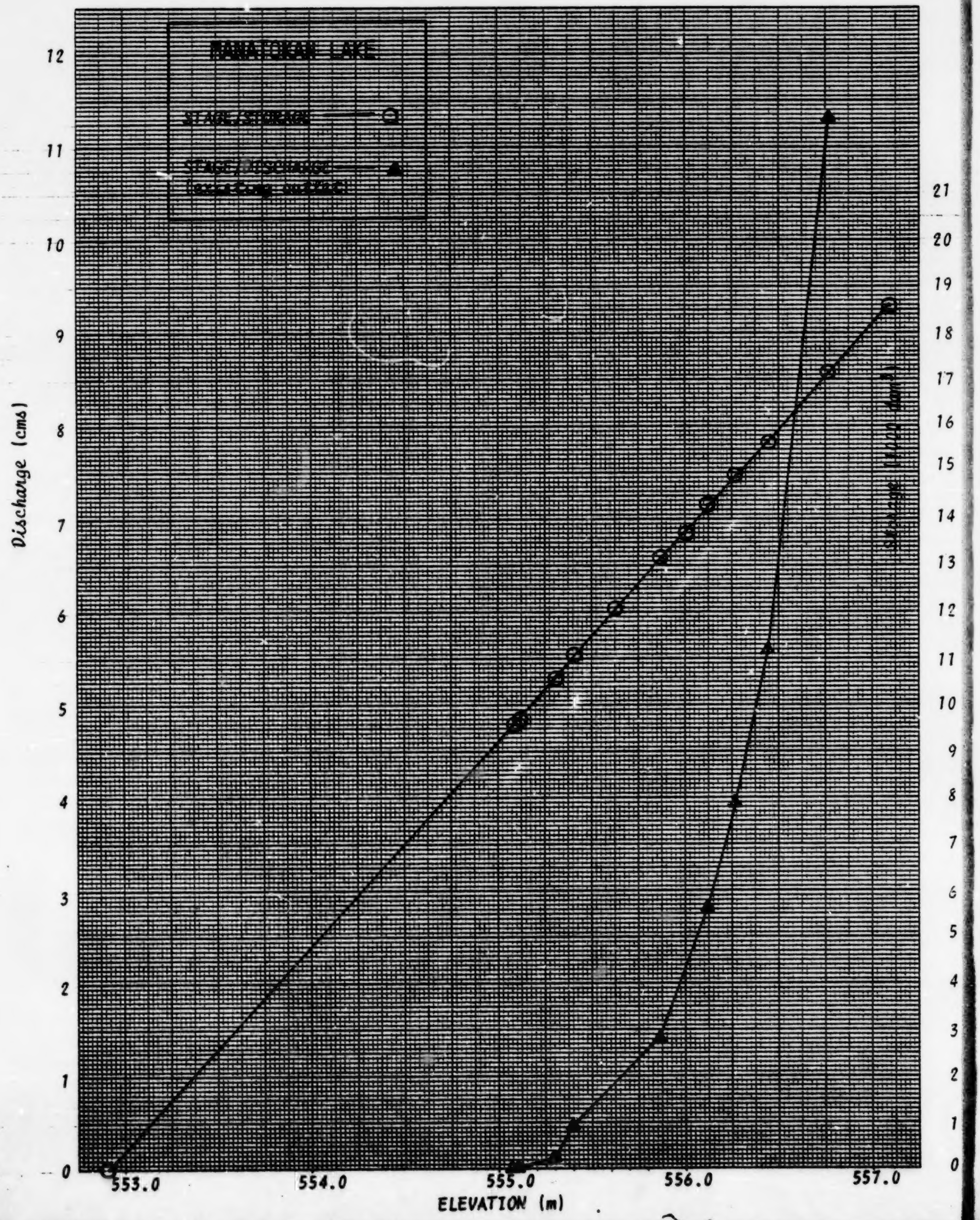
PROJECTED FOR YEAR 2015

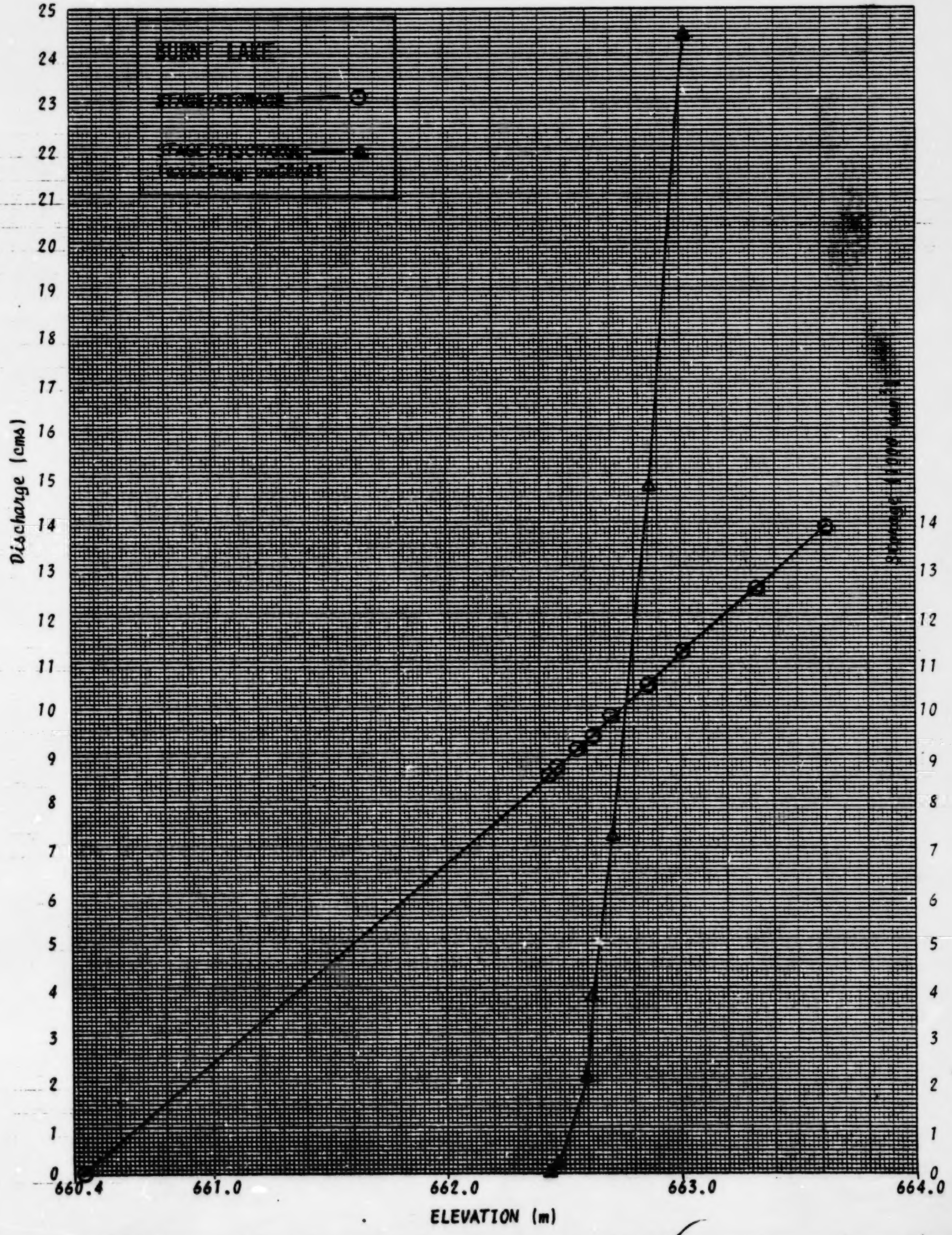
Node Number	Withdrawal Point	Nature of Withdrawal	Withdrawal Amount (dam^3)	
			High	Low
233	Cold Lake	Municipal	8230	5150
210	Moose Lake	Municipal	3170	2710
210	Moose Lake	Irrigation	211	211
503	Beaver @ Goodridge	Municipal	560	520
503	Beaver @ Goodridge	Irrigation	152	152

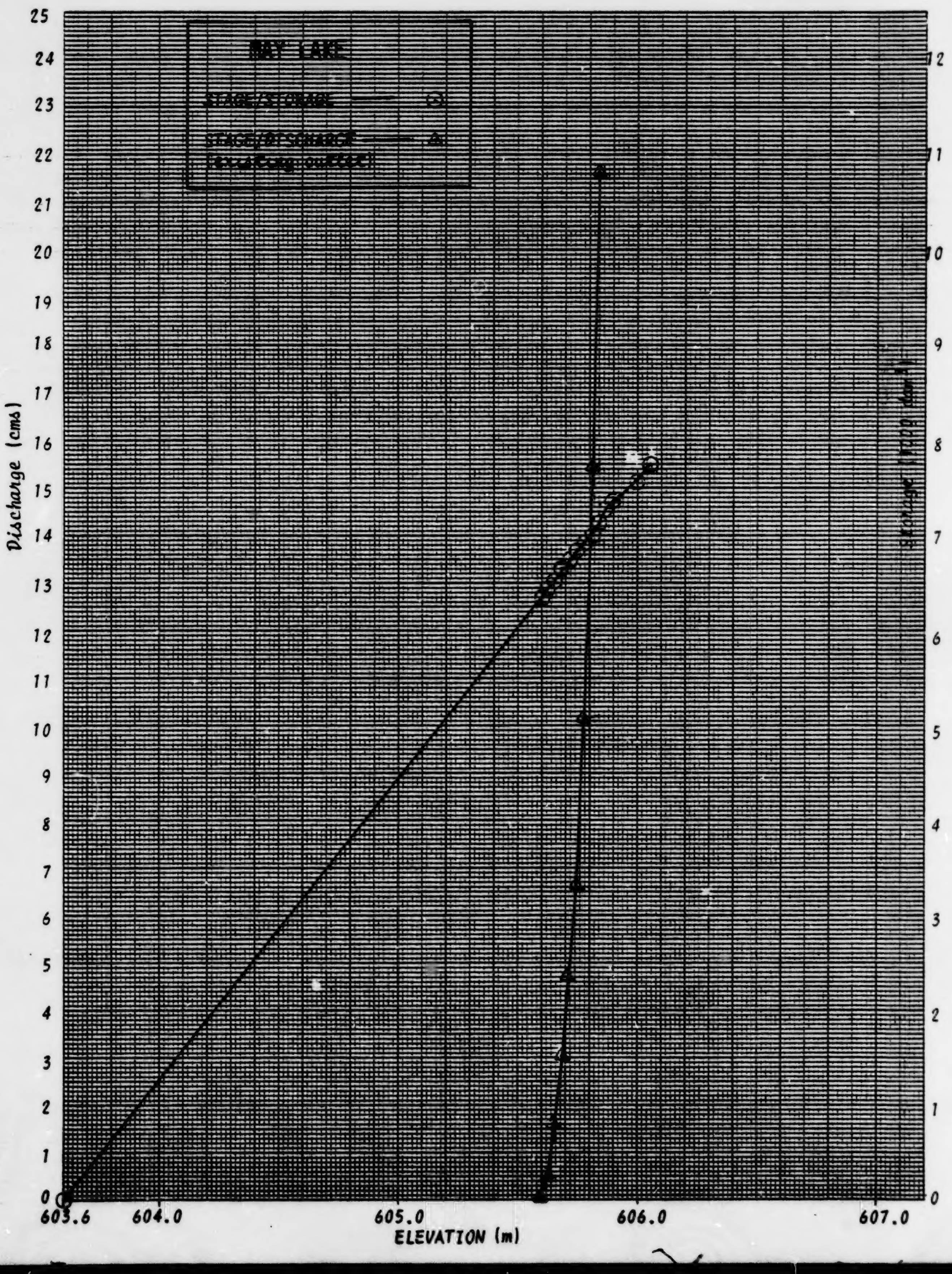
STARTING ELEVATIONS OF LAKES

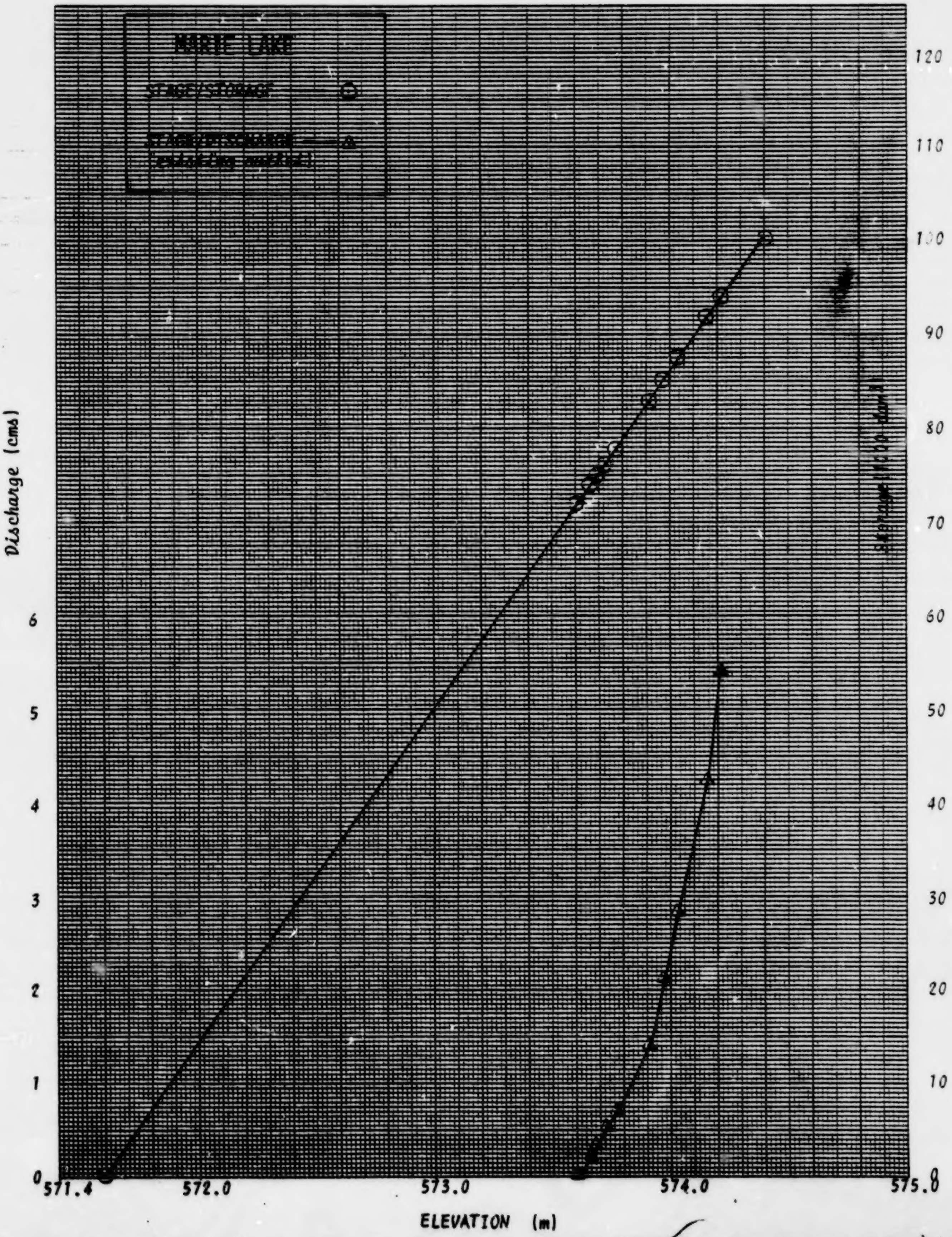
NODE NUMBER	LAKE	ELEVATION (m)
204	Caribou	633.22
206	Wolf	597.271
210	Moose	533.048
212	Manatokan	555.438
216	Tucker	553.75
218	Burnt	662.46
219	May	605.603
220	Marie	573.74
221	Ethel	541.193
223	Muriel	560.10
224	Charlotte	99.48
227	Reita	614.44
228	Angling	556.87
231	Primrose	98.91
233	Cold	534.82

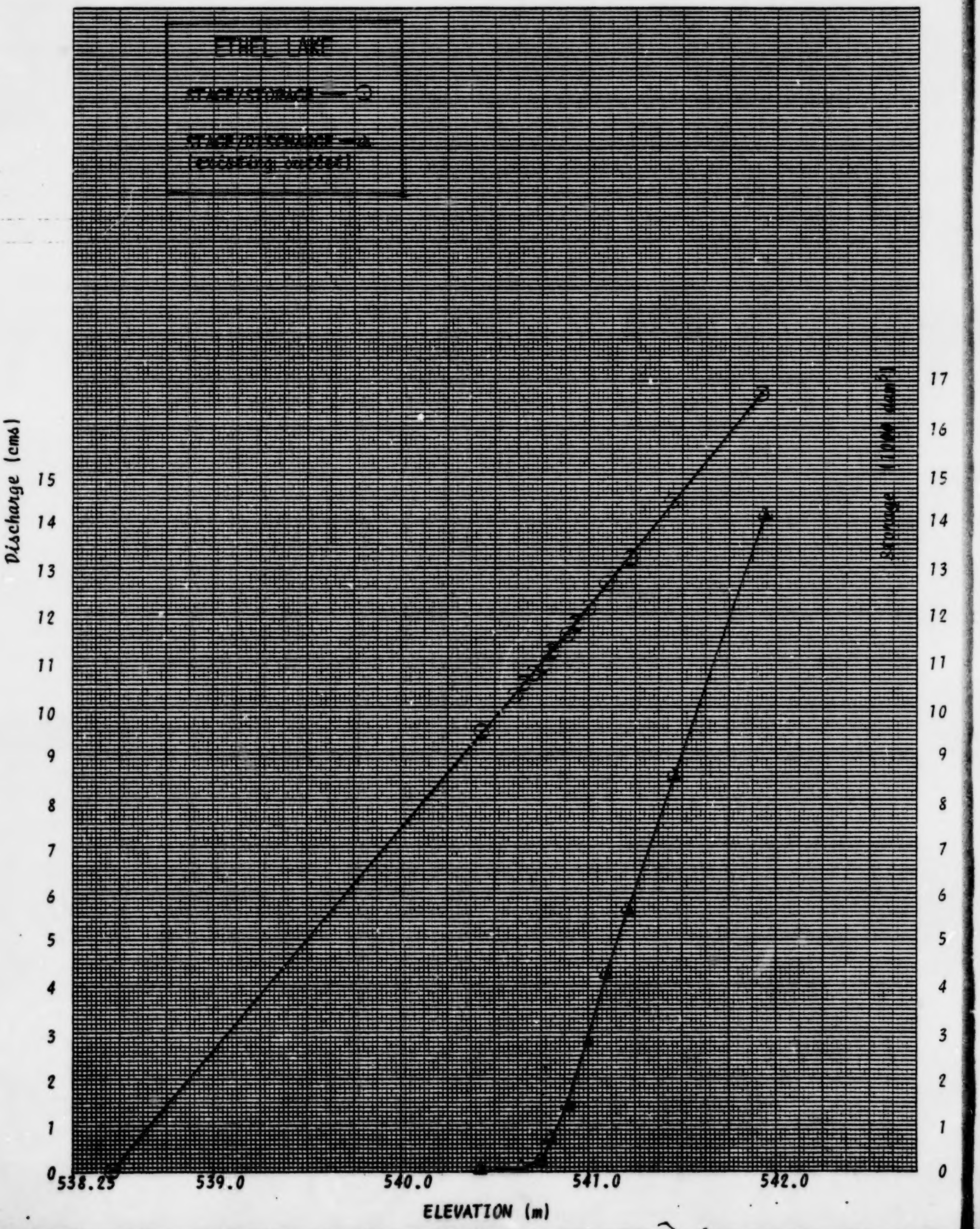

WOLF LAKE
STAGE/STORAGE ——○
STAGE/DISCHARGE ——△
(existing outlet)
Discharge (cms)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Storage (1000 dam³)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
597.0
597.5
598.0
598.5
ELEVATION (m)

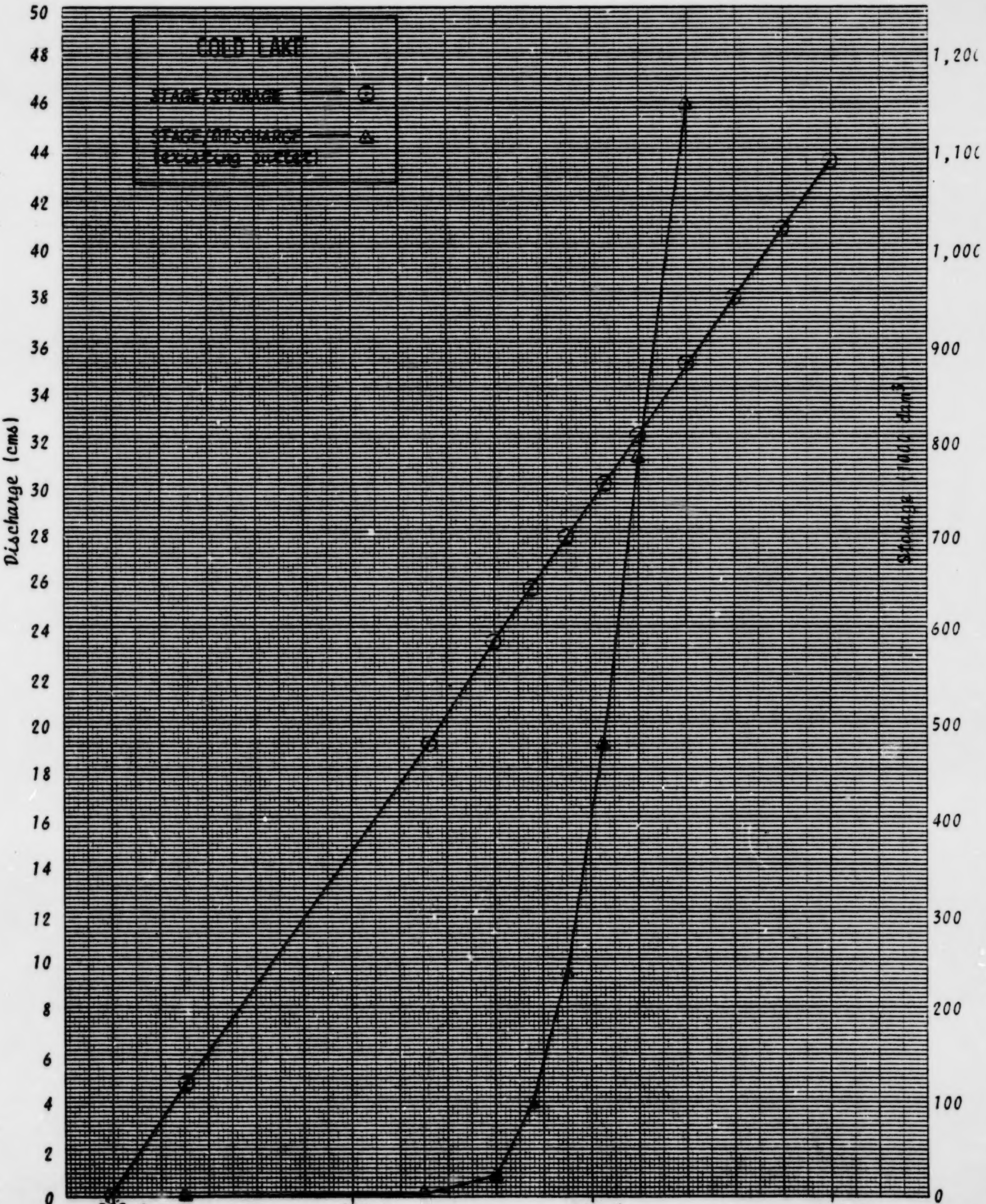

MANATOKAN LAKE
STAGE/STORAGE
STAGE/DISCHARGE
[illegible]
Discharge (cms)
0
1
2
3
4
5
6
7
8
9
10
11
12
Storage (1000 dam³)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
553.0
554.0
555.0
556.0
557.0
ELEVATION (m)

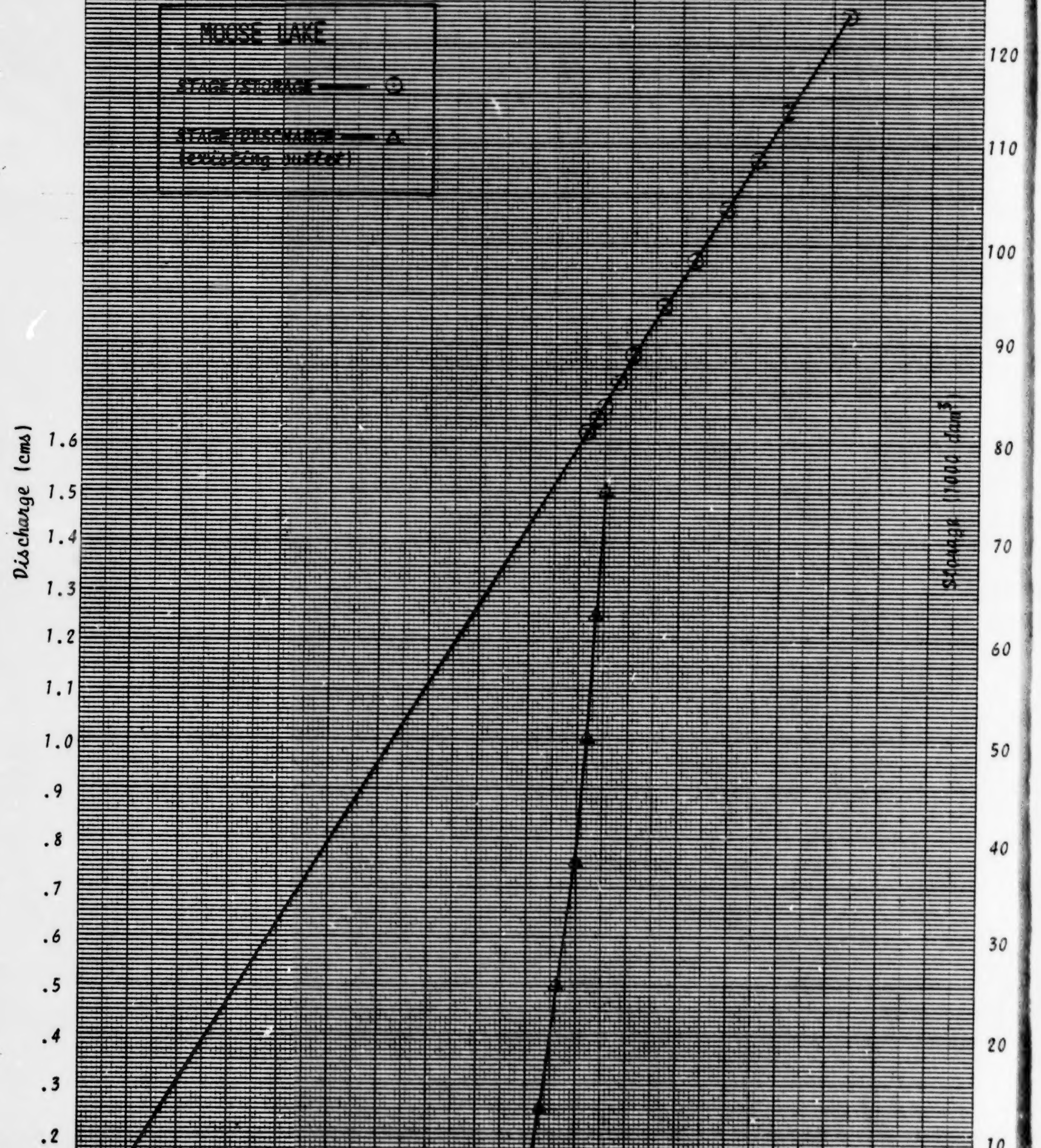

BURNT LAKE
STAGE/STORAGE
STAGE/DISCHARGE
Discharge (cms)
Storage (1000 dam³)
ELEVATION (m)
660.4
661.0
662.0
663.0
664.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

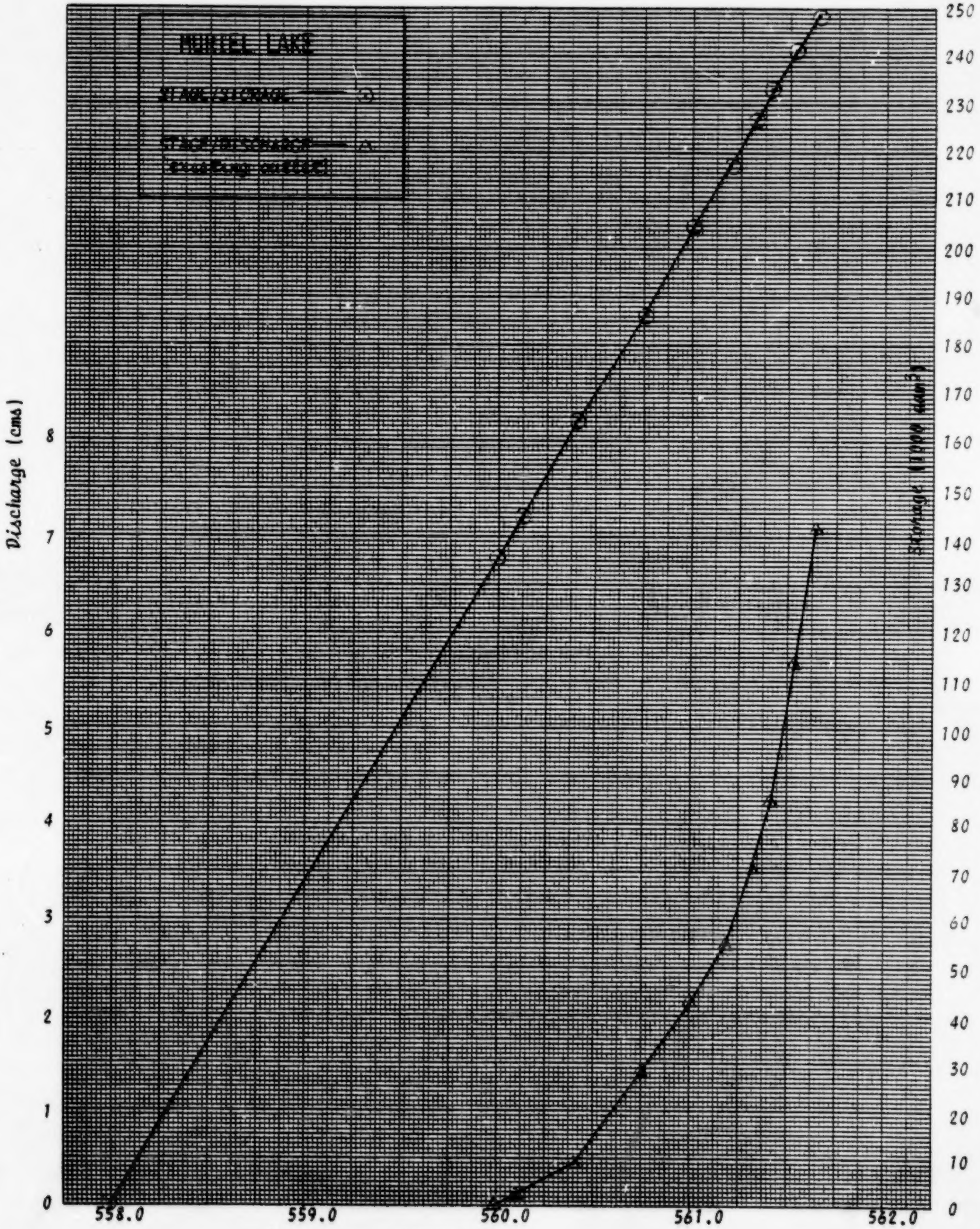

MAY LAKE
STAGE/STORAGE
STAGE/DISCHARGE
(existing outlet)
Discharge (cms)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Storage (1000 dam³)
0
1
2
3
4
5
6
7
8
9
10
11
12
603.6
604.0
605.0
606.0
607.0
ELEVATION (m)

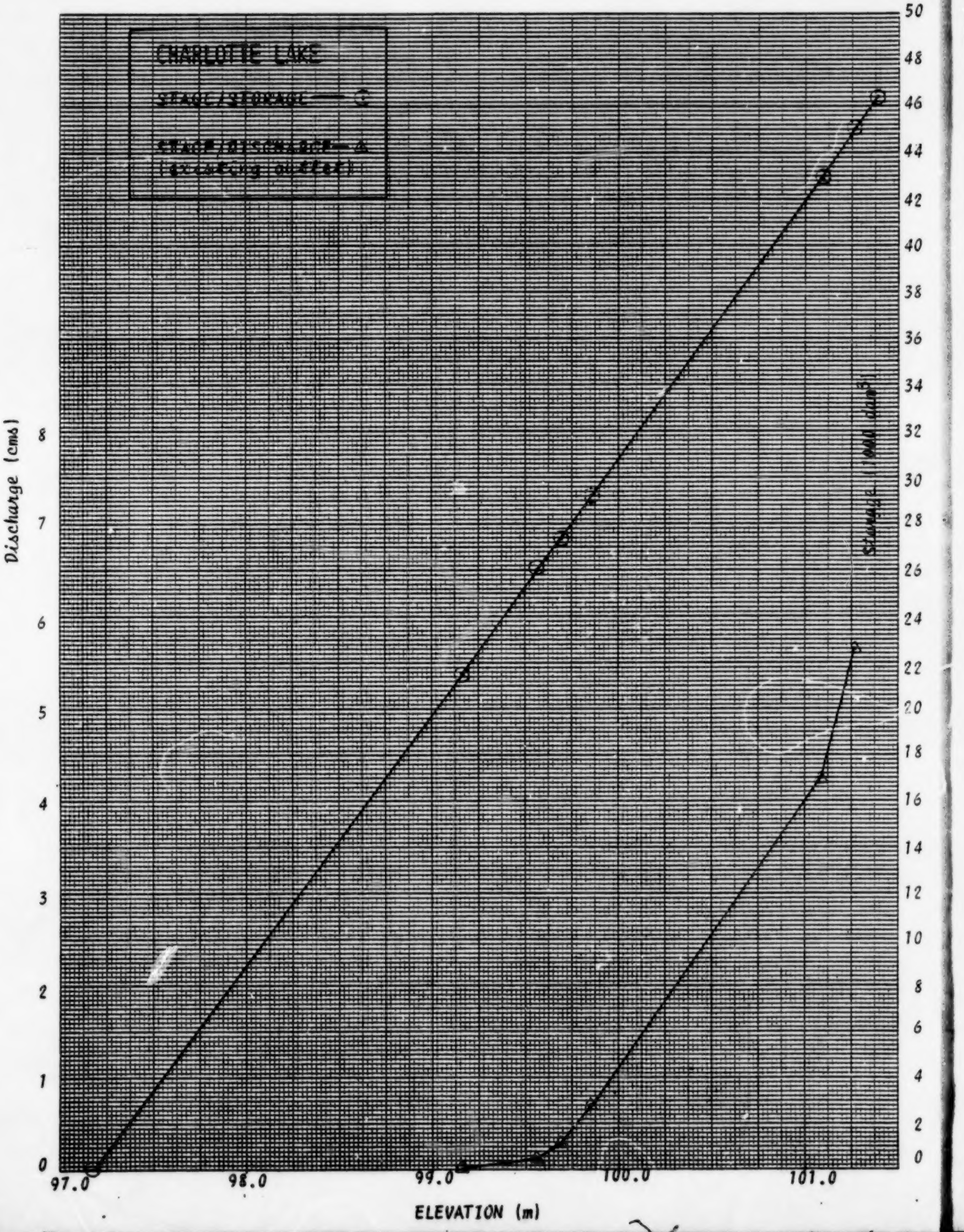

MARIE LAKE
STAGE/STORAGE
STAGE/DISCHARGE
(existing outlet)
Discharge (cms)
Storage (1000 dam³)
ELEVATION (m)
0
1
2
3
4
5
6
10
20
30
40
50
60
70
80
90
100
110
120
571.4
572.0
573.0
574.0
575.8

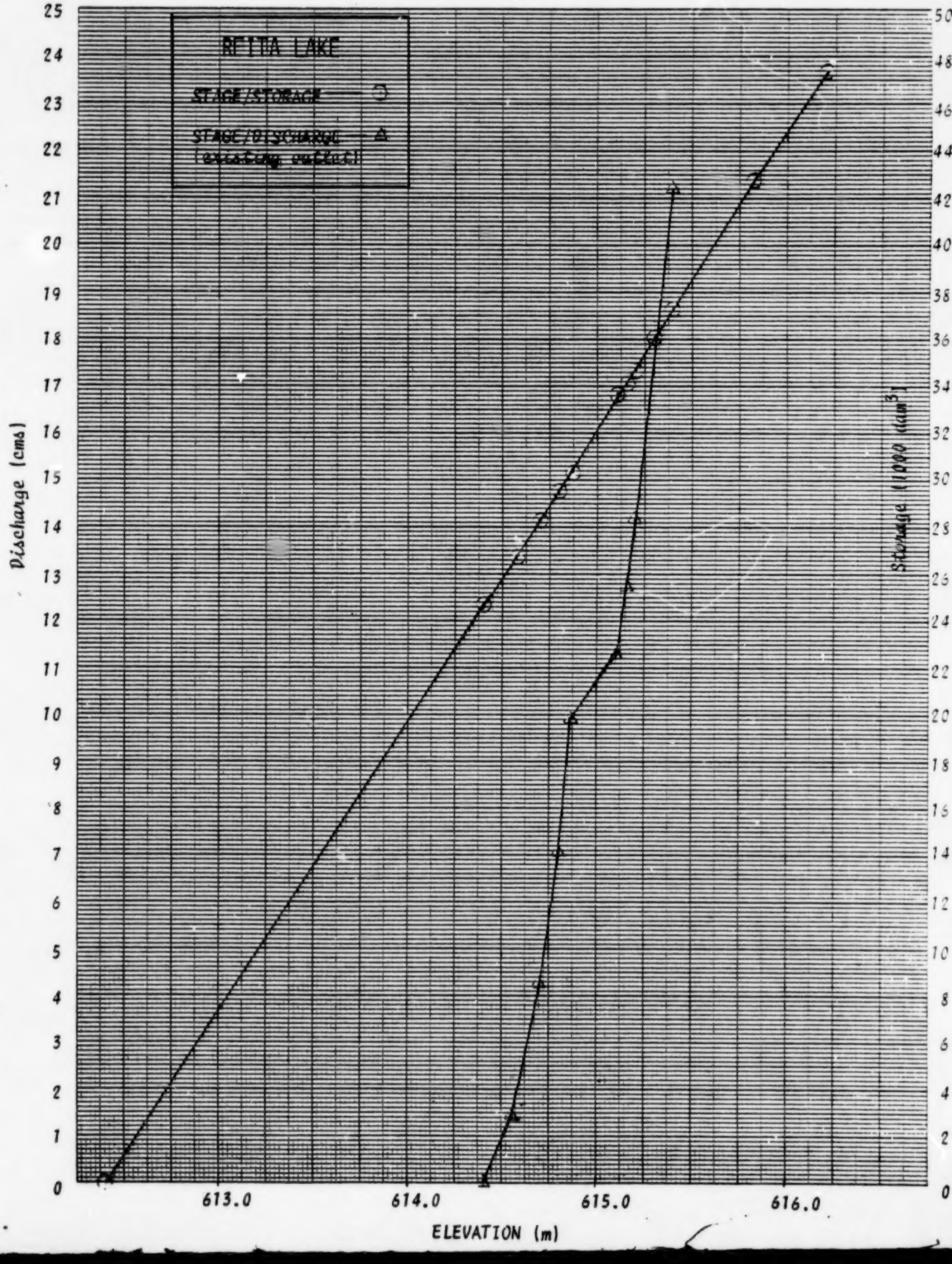

ETHEL LAKE
STAGE/STORAGE —○
STAGE/DISCHARGE —▲
(existing outlet)
Discharge (cms)
Storage (1000 dam³)
ELEVATION (m)
538.25
539.0
540.0
541.0
542.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

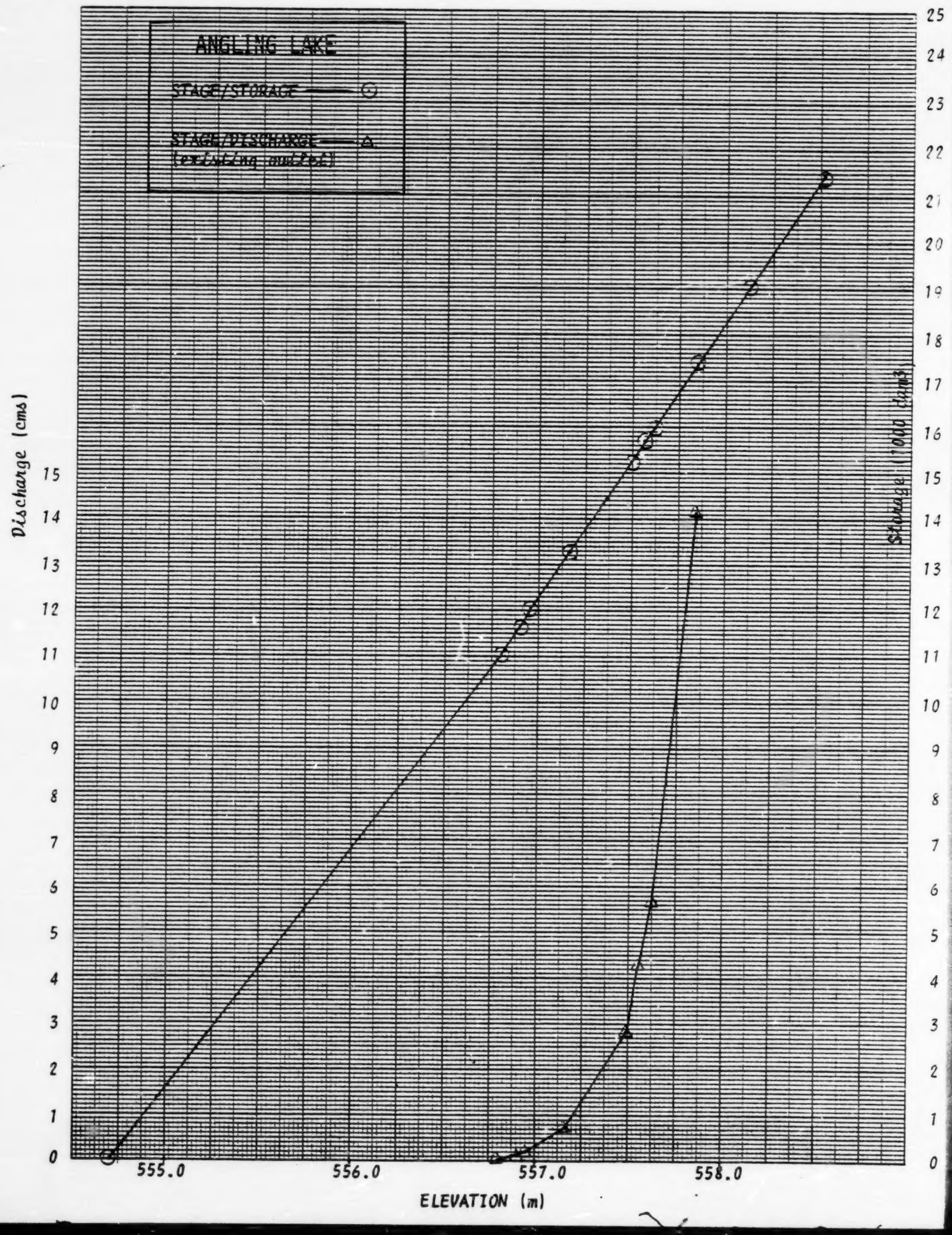

COLD LAKE
STAGE/STORAGE
STAGE/DISCHARGE (existing outlet)
Discharge (cms)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
Storage (1000 dam³)
0
100
200
300
400
500
600
700
800
900
1,00
1,10
1,20
533.0
534.0
535.0
536.0
ELEVATION (m)

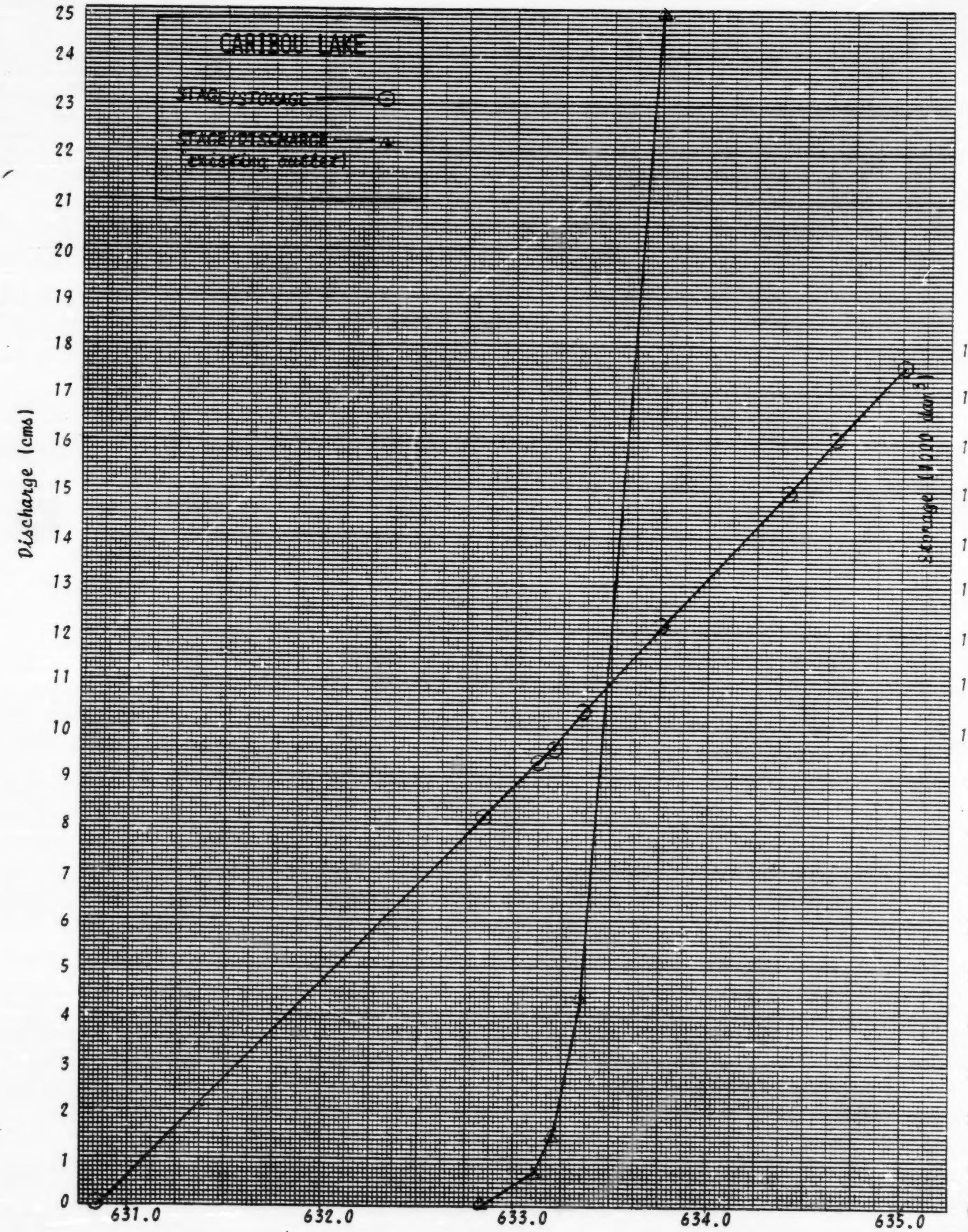

MOOSE LAKE
STAGE/STORAGE ⊙
STAGE/DISCHARGE △
(existing outlet)
Discharge (cms)
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
Storage (1000 dam³)
0
10
20
30
40
50
60
70
80
90
100
110
120
531.0
532.0
533.0
534.0
ELEVATION (m)

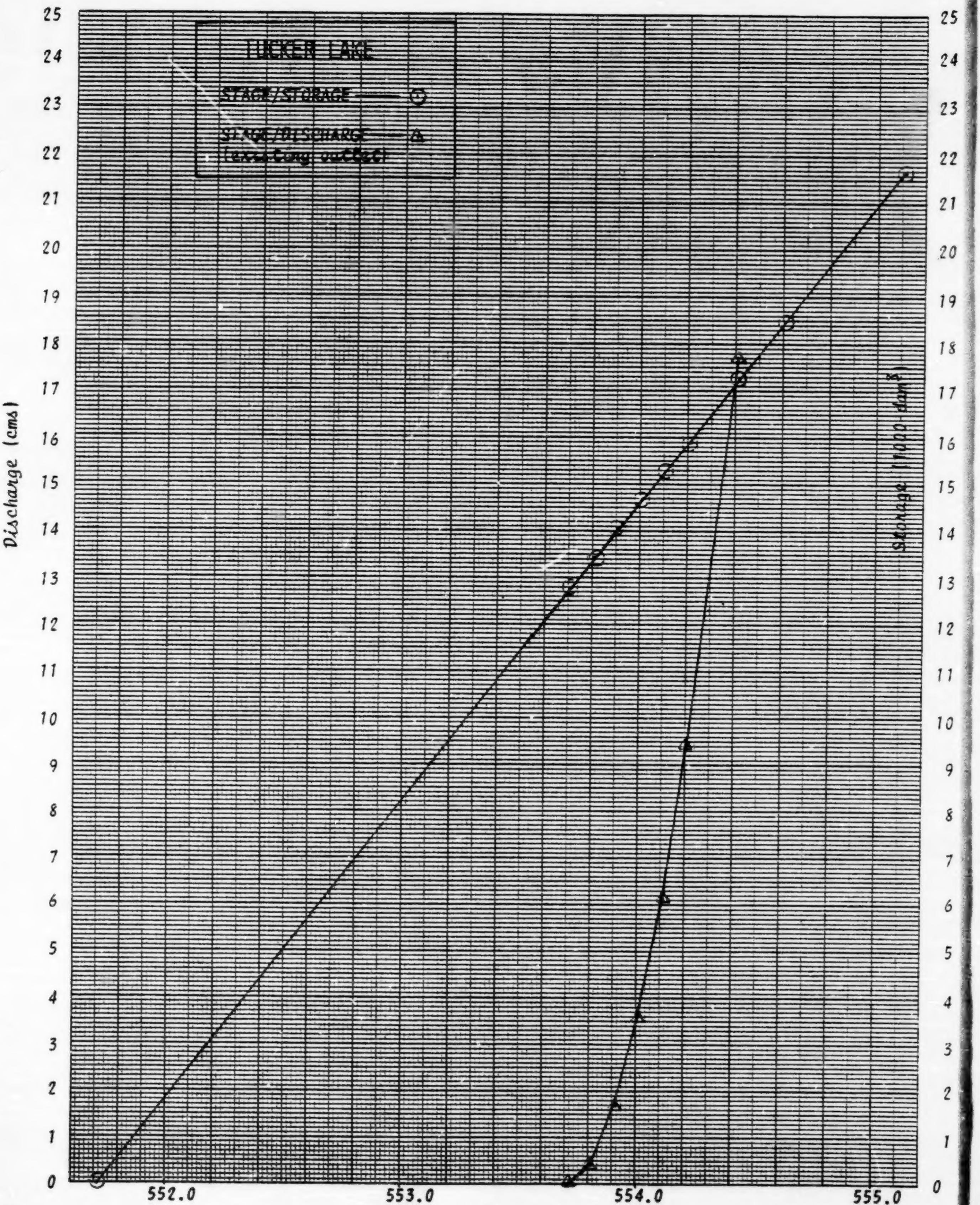

MURIEL LAKE
STAGE/STORAGE ○
STAGE/DISCHARGE △
(existing outlet)
Discharge (cms)
0
1
2
3
4
5
6
7
8
Storage (1000 dam³)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
558.0
559.0
560.0
561.0
562.0
ELEVATION (m)

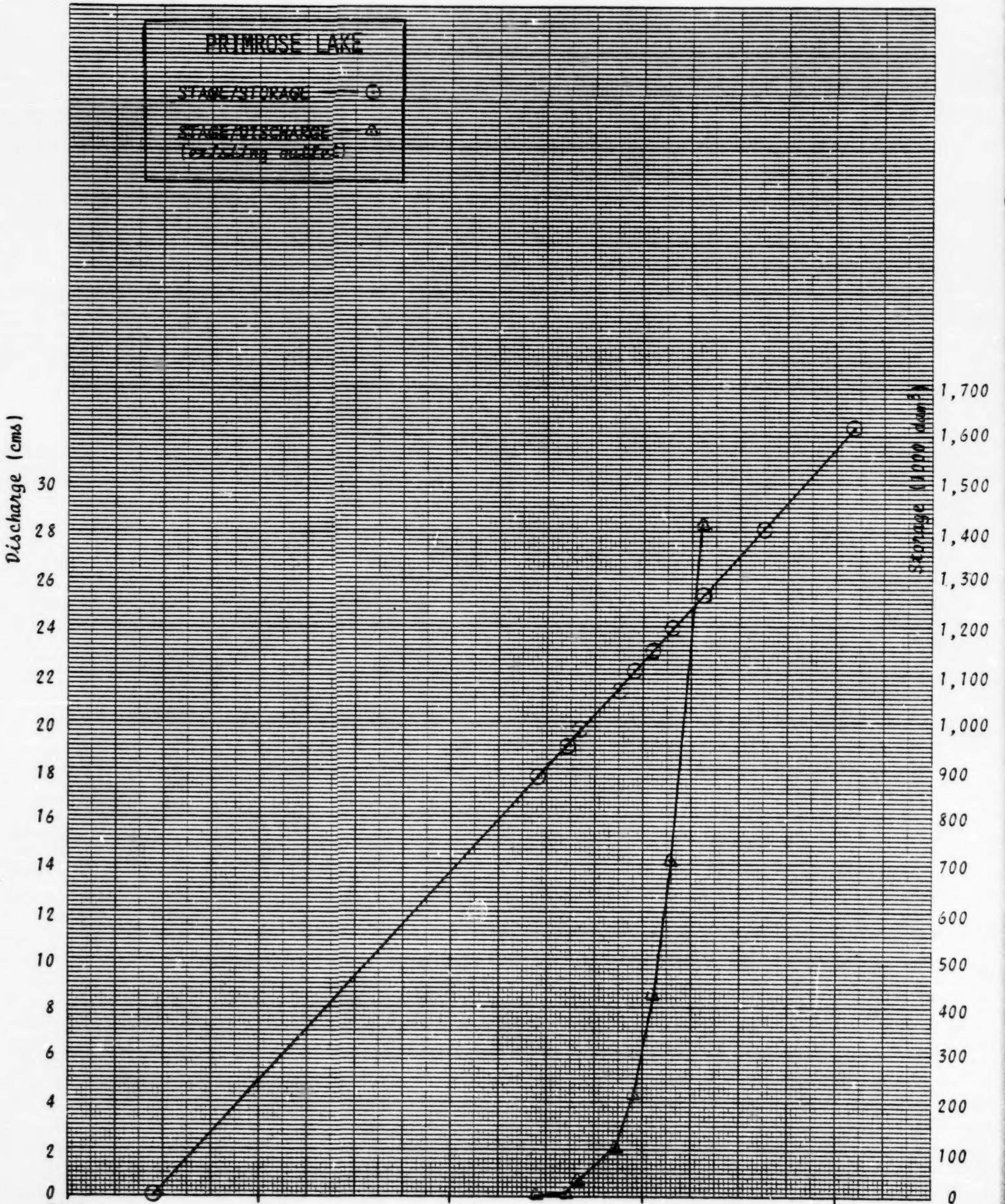

CHARLOTTE LAKE
STAGE/STORAGE — ○
STAGE/DISCHARGE — △
(excluding outlet)
Discharge (cms)
0
1
2
3
4
5
6
7
8
Storage (1000 dam³)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
97.0
98.0
99.0
100.0
101.0
ELEVATION (m)

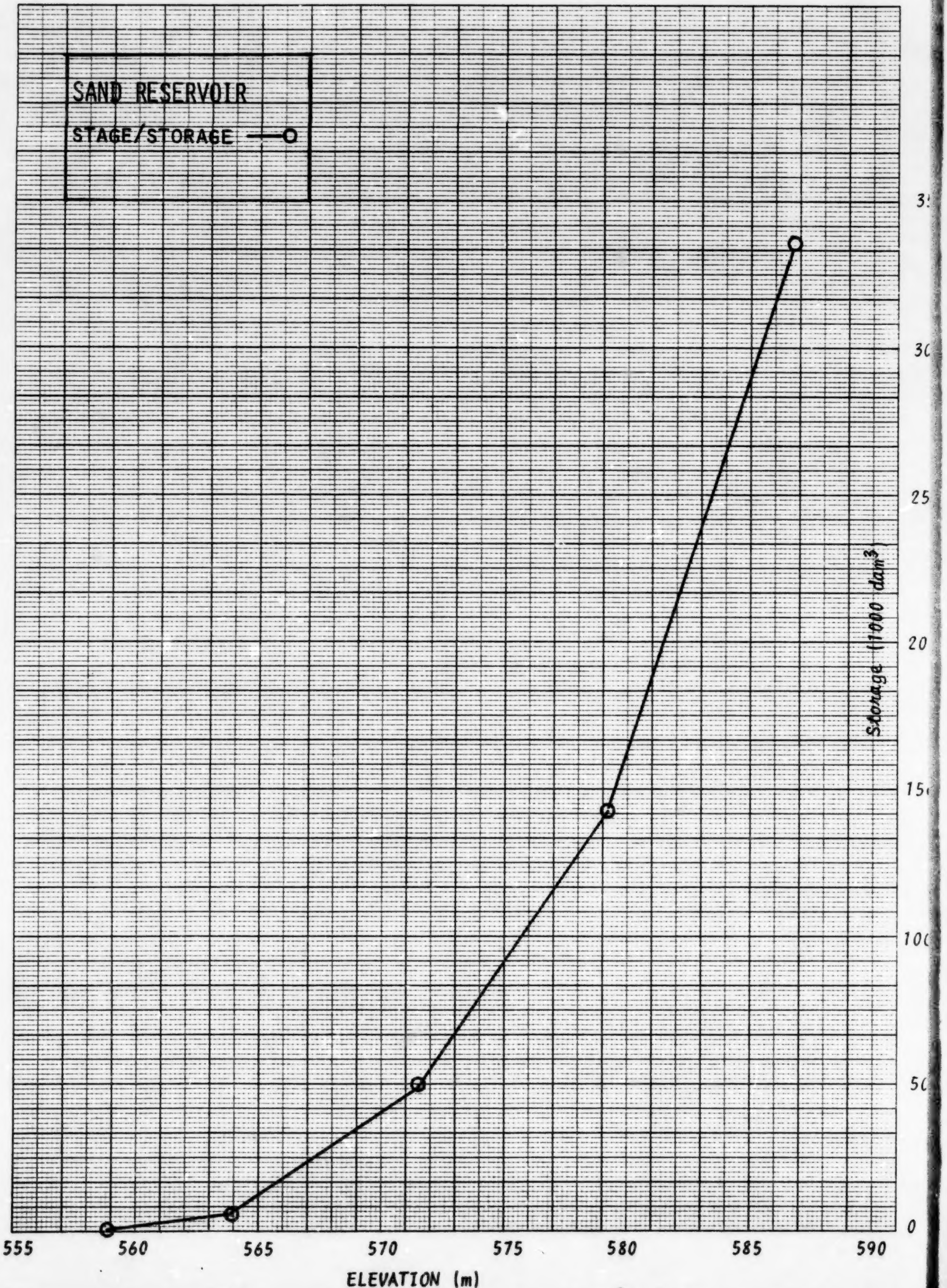

REITA LAKE
STAGE/STORAGE ——— ○
STAGE/DISCHARGE ——— △
(existing outlet)
Discharge (cms)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Storage (1000 dam^3)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
613.0
614.0
615.0
616.0
ELEVATION (m)


ANGLING LAKE
STAGE/STORAGE —— ⊙
STAGE/DISCHARGE —— △
(existing outlet)
Discharge (cms)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Storage ('000 dam3)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
555.0
556.0
557.0
558.0
ELEVATION (m)


CARIBOU LAKE
STAGE/STORAGE
STAGE/DISCHARGE
(existing outlet)
Discharge (cms)
Storage (1000 dam³)
ELEVATION (m)
631.0
632.0
633.0
634.0
635.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25


TUCKER LAKE
STAGE/STORAGE ——— ○
STAGE/DISCHARGE ——— △
(existing outlet)
Discharge (cms)
Storage (1000 dam³)
ELEVATION (m)
552.0
553.0
554.0
555.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25


PRIMROSE LAKE
STAGE/STORAGE —⊙
STAGE/DISCHARGE —△
(existing outlet)
Discharge (cms)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Storage (1000 dam³)
0
100
200
300
400
500
600
700
800
900
1,000
1,100
1,200
1,300
1,400
1,500
1,600
1,700
96.0
97.0
98.0
99.0
100.0
ELEVATION (m)


SAND RESERVOIR
STAGE/STORAGE
ELEVATION (m)
Storage (1000 dam^3)
555
560
565
570
575
580
585
590
0
5(
10(
15(
20
25
3(
3

REVISED MONTHLY INFLOWS TO COLD LAKE

NATURAL INFLOW (CMS) - COLD LAKE

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1956	10.53	8.12	8.85	20.52	24.51	38.64	26.04	15.49	14.35	11.80	0.74	10.83
1957	8.20	11.35	12.19	14.09	25.27	17.23	29.81	17.08	6.88	12.50	4.25	2.34
1958	13.62	13.88	9.40	46.70	40.06	20.43	5.18	2.74	4.25	1.05	-5.46	5.58
1959	9.01	8.51	6.60	17.65	17.61	27.30	17.00	18.07	33.84	25.18	14.87	17.26
1960	17.32	18.87	20.91	35.72	47.24	64.32	52.85	65.44	65.03	28.92	16.74	18.98
1961	22.69	22.88	22.03	34.43	64.41	34.22	29.25	20.44	-13.40	-0.30	-3.28	4.51
1962	11.54	7.55	8.62	21.19	47.36	90.25	44.67	22.00	14.75	13.35	5.47	25.98
1963	25.95	22.26	22.32	25.14	34.91	29.52	23.34	22.16	-3.28	-3.62	0.30	-3.10
1964	1.81	3.33	-7.53	25.79	43.60	16.19	12.59	11.36	17.30	16.89	-1.60	8.30
1965	9.37	13.30	17.64	19.43	58.21	122.24	47.38	25.77	18.80	17.56	7.91	15.70
1966	20.35	14.45	12.83	23.41	18.35	18.55	19.51	19.84	7.56	-5.96	-8.90	4.09
1967	8.84	6.36	8.03	7.81	18.03	10.83	8.79	1.52	-6.73	-9.69	-7.94	-1.10
1968	2.35	3.96	4.95	5.76	6.36	5.73	1.98	4.51	10.32	4.39	-4.84	-0.41
1969	6.74	7.63	19.73	23.75	28.02	16.62	7.49	10.05	4.47	3.65	1.30	-0.52
1970	5.48	8.36	9.99	21.67	17.35	50.87	65.53	50.38	33.51	24.32	17.26	23.97
1971	25.53	15.58	22.07	30.51	37.39	32.69	51.85	24.40	2.77	-2.22	-0.09	1.92
1972	9.50	9.64	8.71	20.36	39.84	20.20	14.06	8.33	-5.42	0.19	-4.35	1.63
1973	6.80	2.61	12.70	13.31	30.88	46.74	40.30	44.84	32.34	38.23	24.63	28.28
1974	27.54	25.65	21.72	60.32	103.84	69.13	48.48	26.70	29.04	27.47	18.78	9.74
1975	21.73	15.37	16.29	22.79	45.23	55.14	43.80	27.18	18.59	12.50	7.07	13.47
1976	13.28	9.94	9.88	22.48	19.10	23.16	39.58	24.13	13.35	7.86	3.65	6.91
1977	4.80	8.49	11.05	16.84	23.91	23.94	22.22	15.72	8.72	1.20	-3.97	8.66
1978	5.06	3.87	10.01	14.94	55.51	31.21	13.01	14.76	4.84	0.08	-5.45	2.85
1979	5.40	5.33	8.65	15.85	18.76	40.74	24.13	16.10	18.59	9.48	2.73	6.61
1980	6.25	5.08	10.56	10.20	9.91	8.43	8.90	15.76	21.92	15.49	9.98	6.86
1981	10.25	8.85	10.05	14.39	12.52	8.99	12.40	-11.29	-6.36	-4.27	-3.53	2.14
MEAN	11.92	10.82	12.24	22.50	34.16	35.51	27.31	19.75	13.31	9.46	3.32	8.52
MIN.	1.81	2.61	-7.53	5.76	6.36	5.73	1.98	-11.29	-13.40	-9.69	-8.90	-3.10
MAX.	27.54	25.65	22.32	60.32	103.84	122.24	65.53	65.44	65.03	38.23	24.63	28.28

APPENDIX C

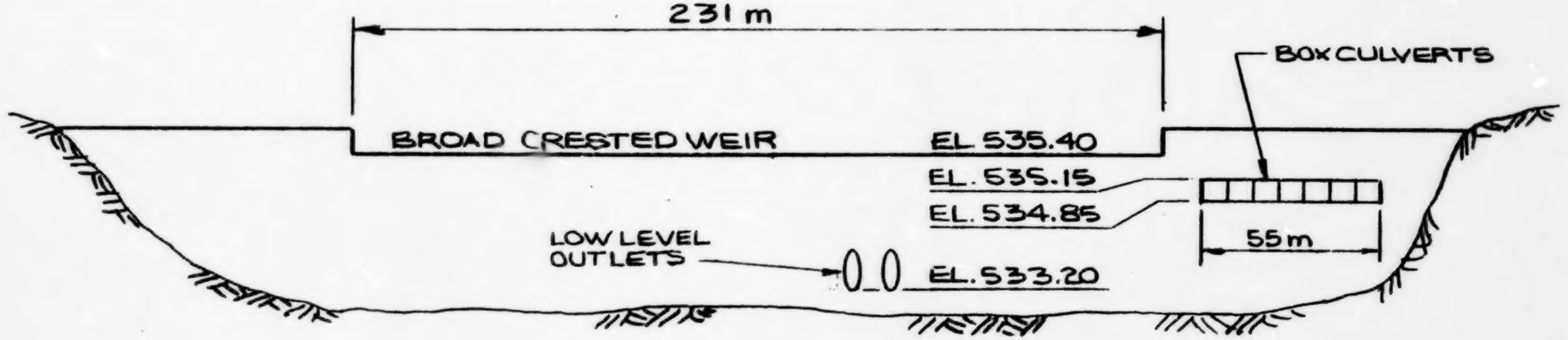
CHARACTERISTICS OF UNATTENDED OUTLETS

APPENDIX C

PHYSICAL CONFIGURATION OF UNATTENDED OUTLETS

The water balance model uses a stage/discharge table to specify the nature of a regulated outlet. In the sub-basin analyses, the stage/discharge tables were adjusted to produce outflow and lake elevations which satisfied the operating criteria. The physical configuration of each outlet was not determined but to ensure that a structure could be built to release water in accordance with the desired stage/discharge table, a conceptual outlet was designed for Cold Lake.

The physical configuration of the outlet is illustrated in Figure C.1. The stage/discharge curve for this structure is compared to that used in the water balance model in Figure C.2. At the lowest water levels, two 600mm diameter culverts control outflows to a water surface elevation of 534.85. Here, a multiple box culvert, 55m long, performing initially as a weir, changes the slope of the stage/discharge curve dramatically. When the box culverts are submerged, above elevation 535.15, the stage/discharge curve flattens somewhat and, if stop logs are placed to reduce the net width of the box culverts by 37%, the change is substantial. The effect of not using stop logs is shown on the stage/discharge curve. Above elevation 535.40 the broad crested weir takes effect and dominates all discharges above elevation 535.70.


231 m
BOX CULVERTS
BROAD CRESTED WEIR
EL 535.40
EL. 535.15
EL. 534.85
55 m
LOW LEVEL OUTLETS
EL. 533.20

SCALE HORIZ. 1:2000
VERT. 1:100

CONCEPTUAL DESIGN
UNATTENDED OUTLET
COLD LAKE

BEAVER RIVER - COLD LAKE
REGIONAL WATER RESOURCES STUDY
FIGURE C.1

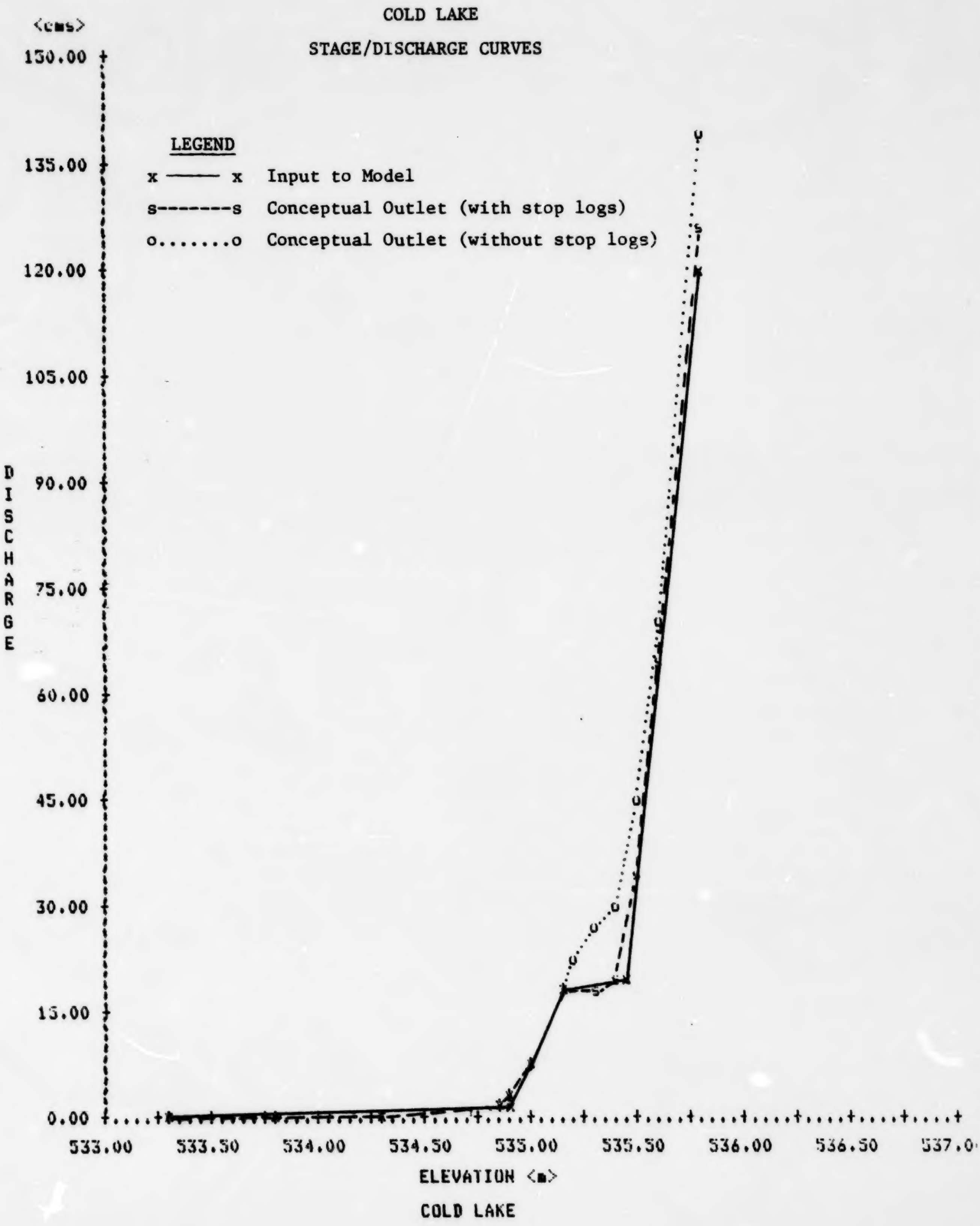
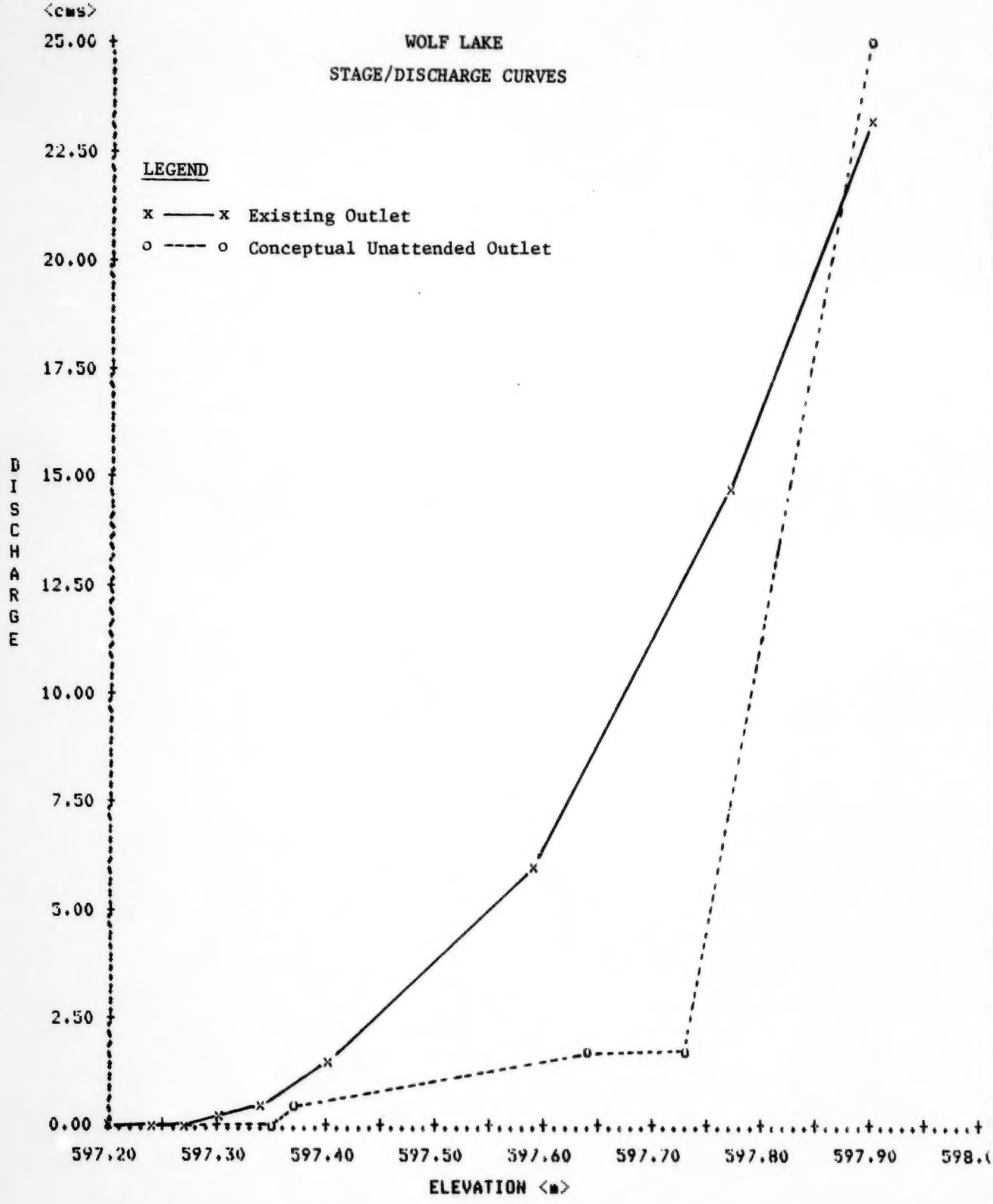
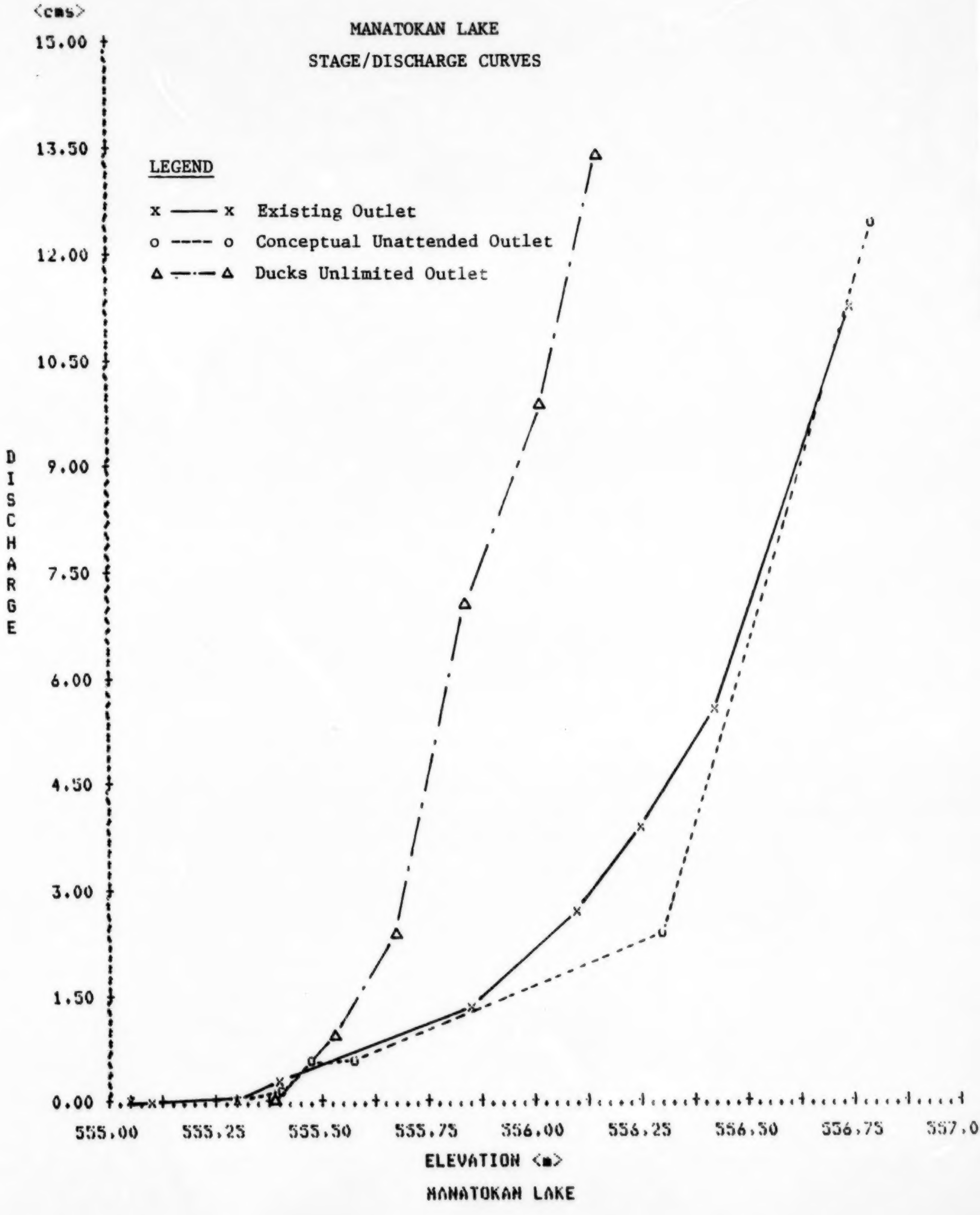

COLD LAKE
STAGE/DISCHARGE CURVES
<cms>
150.00
135.00
120.00
105.00
90.00
75.00
60.00
45.00
30.00
15.00
0.00
DISCHARGE
LEGEND
x —— x Input to Model
s-------s Conceptual Outlet (with stop logs)
o.......o Conceptual Outlet (without stop logs)
533.00
533.50
534.00
534.50
535.00
535.50
536.00
536.50
537.0
ELEVATION <m>
COLD LAKE

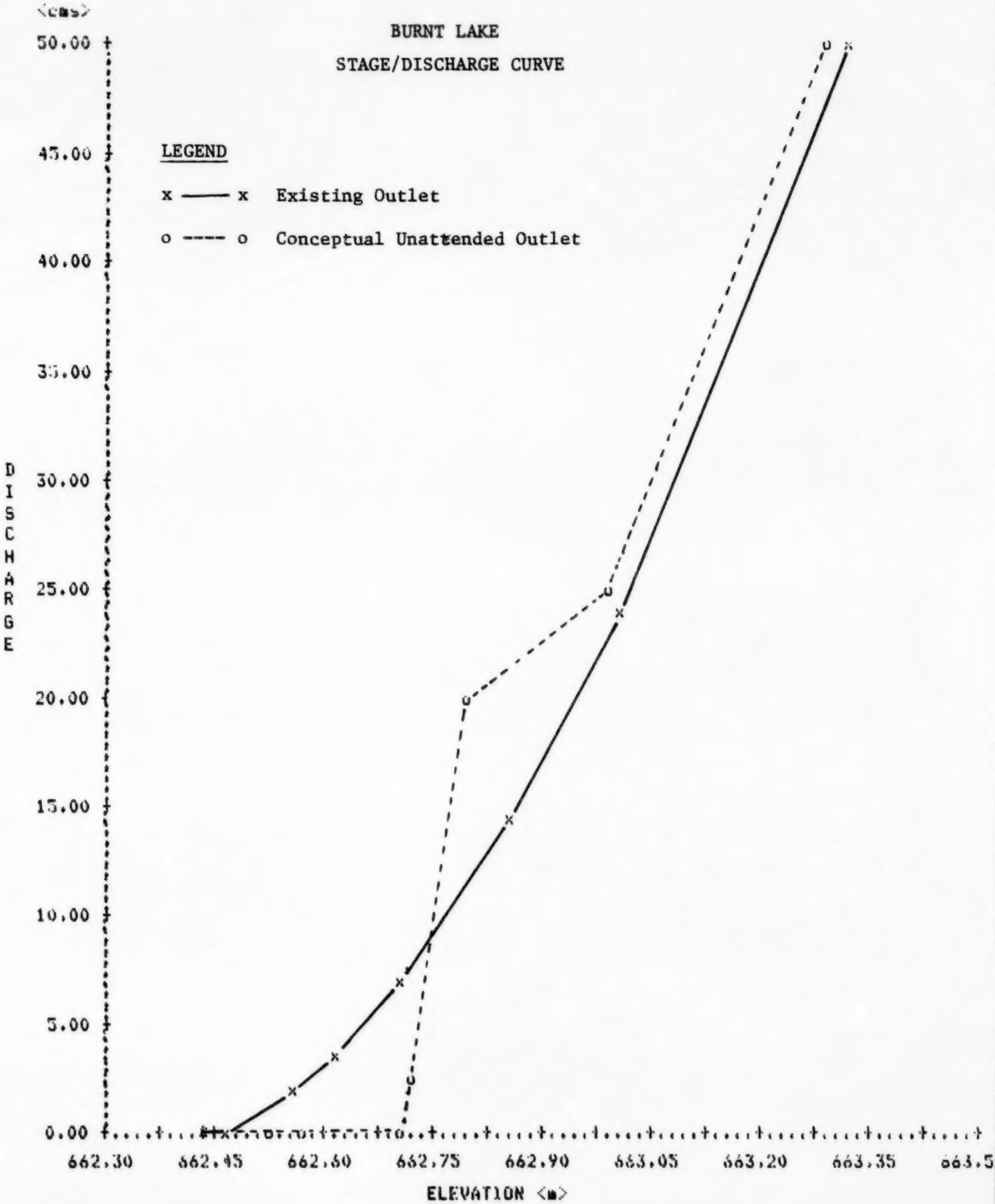
FIGURE C.2


WOLF LAKE
STAGE/DISCHARGE CURVES
LEGEND
x ——— x Existing Outlet
o ---- o Conceptual Unattended Outlet
<cms>
DISCHARGE
25.00
22.50
20.00
17.50
15.00
12.50
10.00
7.50
5.00
2.50
0.00
597.20
597.30
597.40
597.50
597.60
597.70
597.80
597.90
598.
ELEVATION <m>

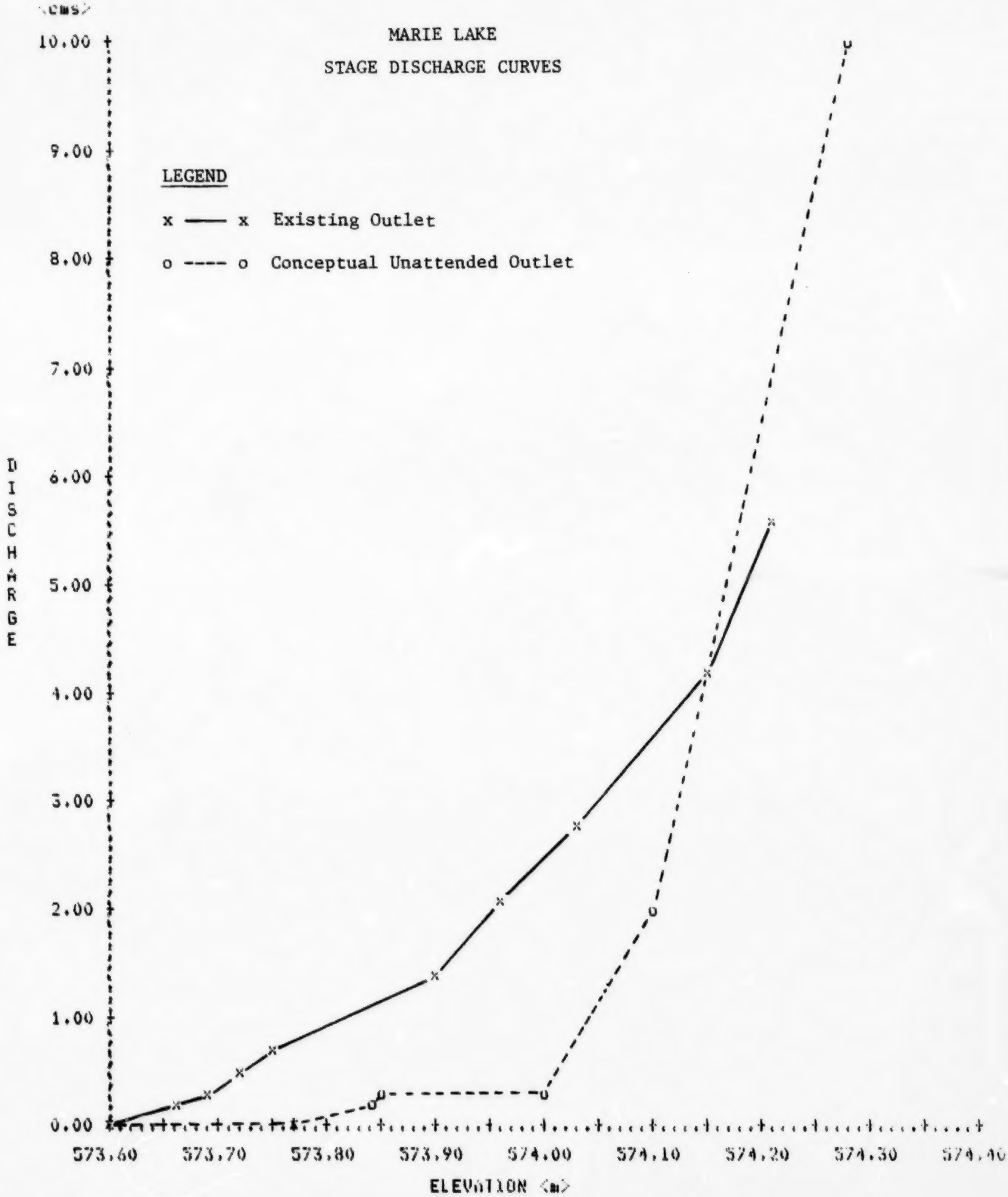
WOLF LAKE



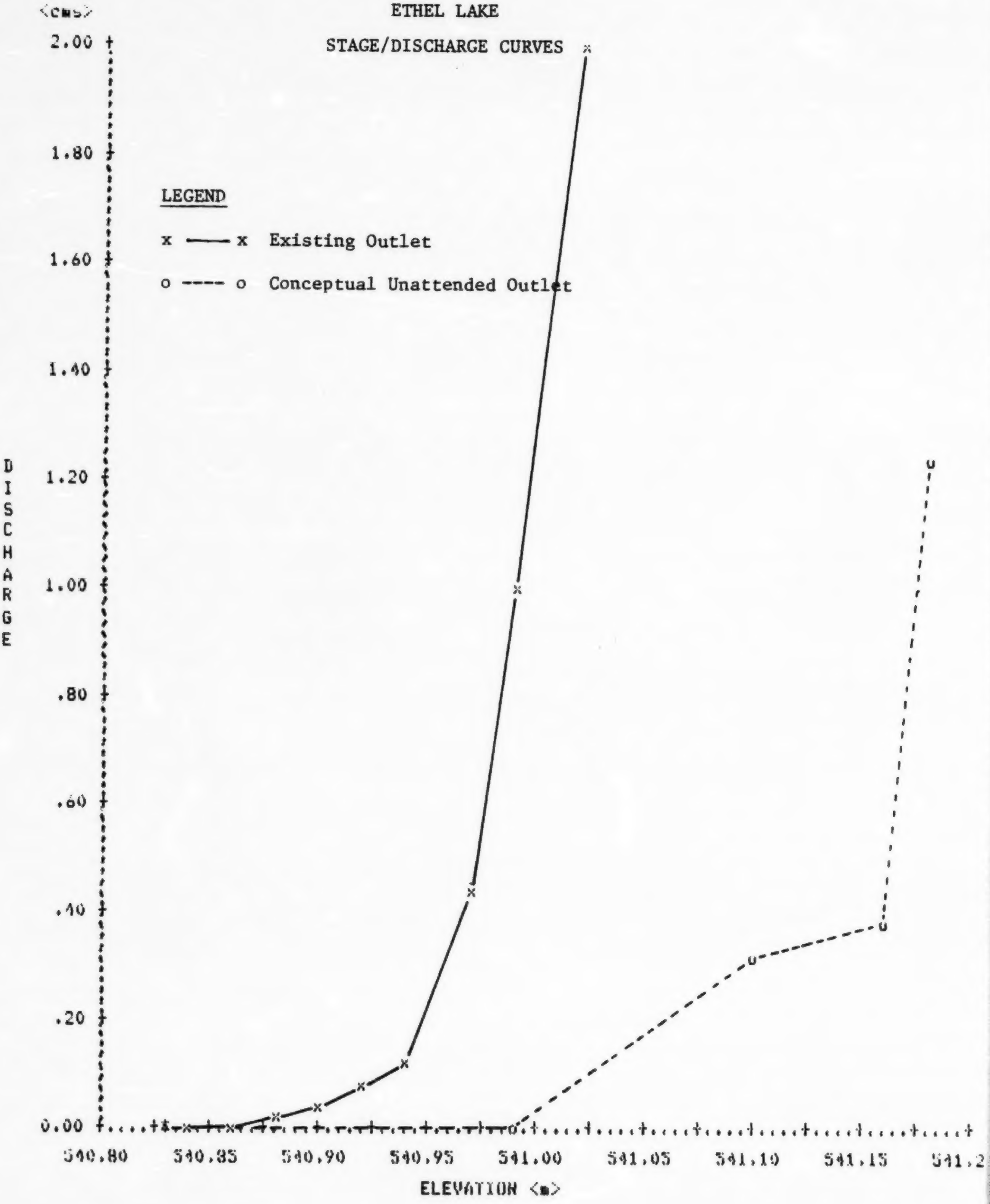
<cms>
MANATOKAN LAKE
STAGE/DISCHARGE CURVES
15.00
13.50
12.00
10.50
9.00
7.50
6.00
4.50
3.00
1.50
0.00
DISCHARGE
LEGEND
x —— x Existing Outlet
o ---- o Conceptual Unattended Outlet
Δ —·— Δ Ducks Unlimited Outlet
555.00
555.25
555.50
555.75
556.00
556.25
556.50
556.75
557.0
ELEVATION <m>
MANATOKAN LAKE


BURNT LAKE
STAGE/DISCHARGE CURVE
LEGEND
x —— x Existing Outlet
o ---- o Conceptual Unattended Outlet
<cms>
DISCHARGE
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
662.30
662.45
662.60
662.75
662.90
663.05
663.20
663.35
663.5
ELEVATION <m>

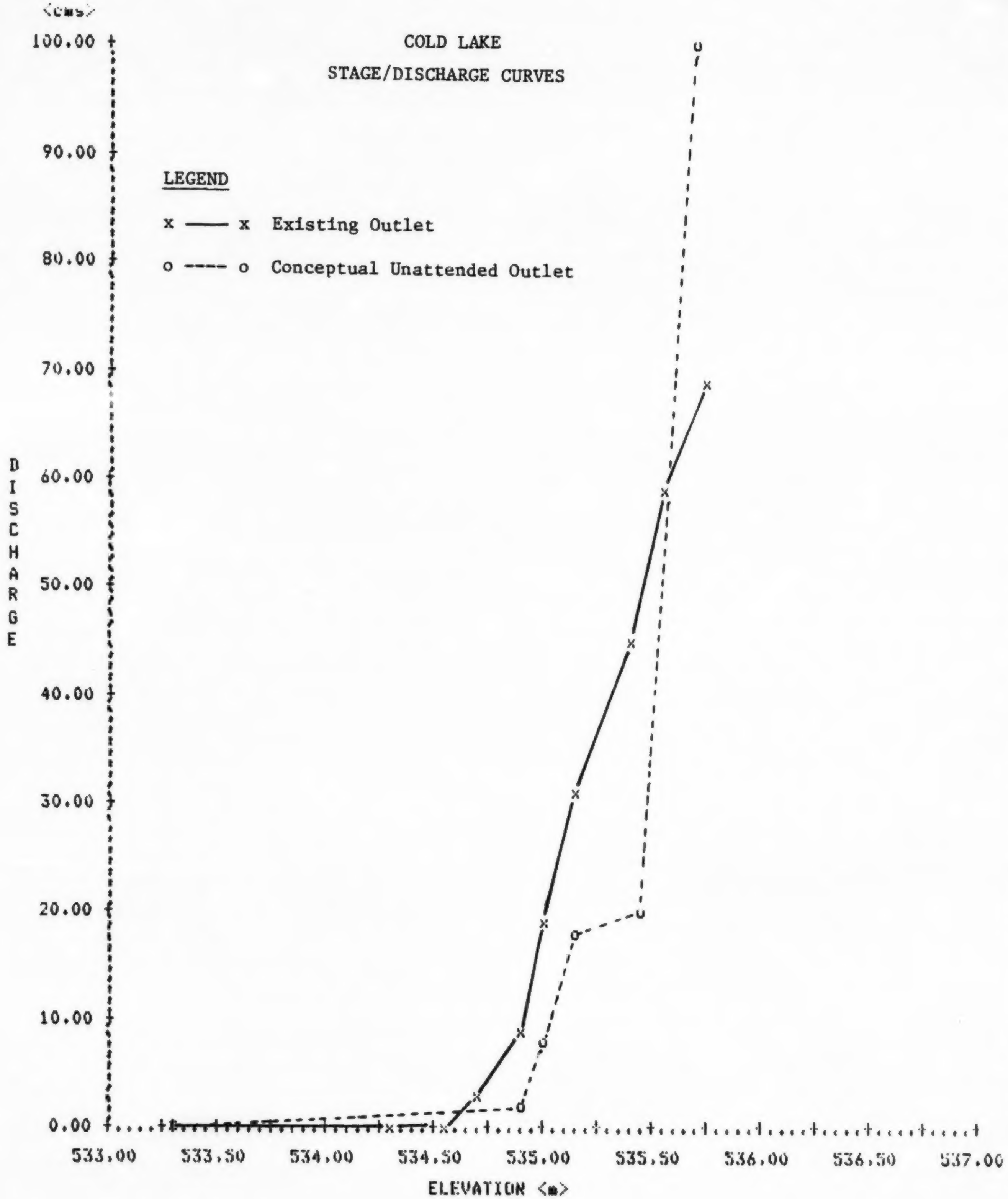
BURNT LAKE


MARIE LAKE
STAGE DISCHARGE CURVES
LEGEND
x —— x Existing Outlet
o ---- o Conceptual Unattended Outlet
<cms>
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
DISCHARGE
573.60
573.70
573.80
573.90
574.00
574.10
574.20
574.30
574.40
ELEVATION <m>

MARIE LAKE

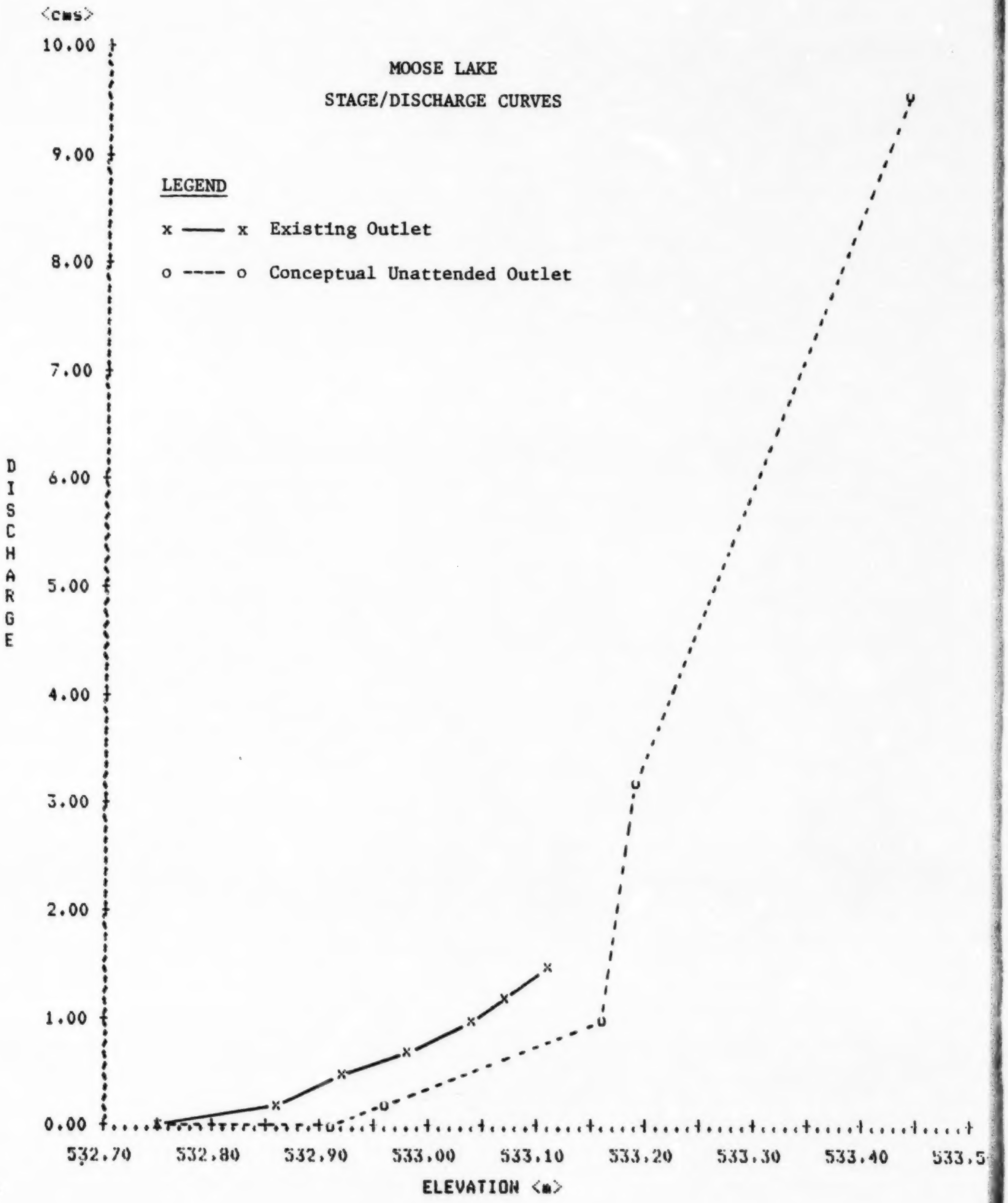

ETHEL LAKE
STAGE/DISCHARGE CURVES
<cms>
DISCHARGE
2.00
1.80
1.60
1.40
1.20
1.00
.80
.60
.40
.20
0.00
LEGEND
x —— x Existing Outlet
o ---- o Conceptual Unattended Outlet
540.80
540.85
540.90
540.95
541.00
541.05
541.10
541.15
541.2
ELEVATION <m>

ETHEL LAKE

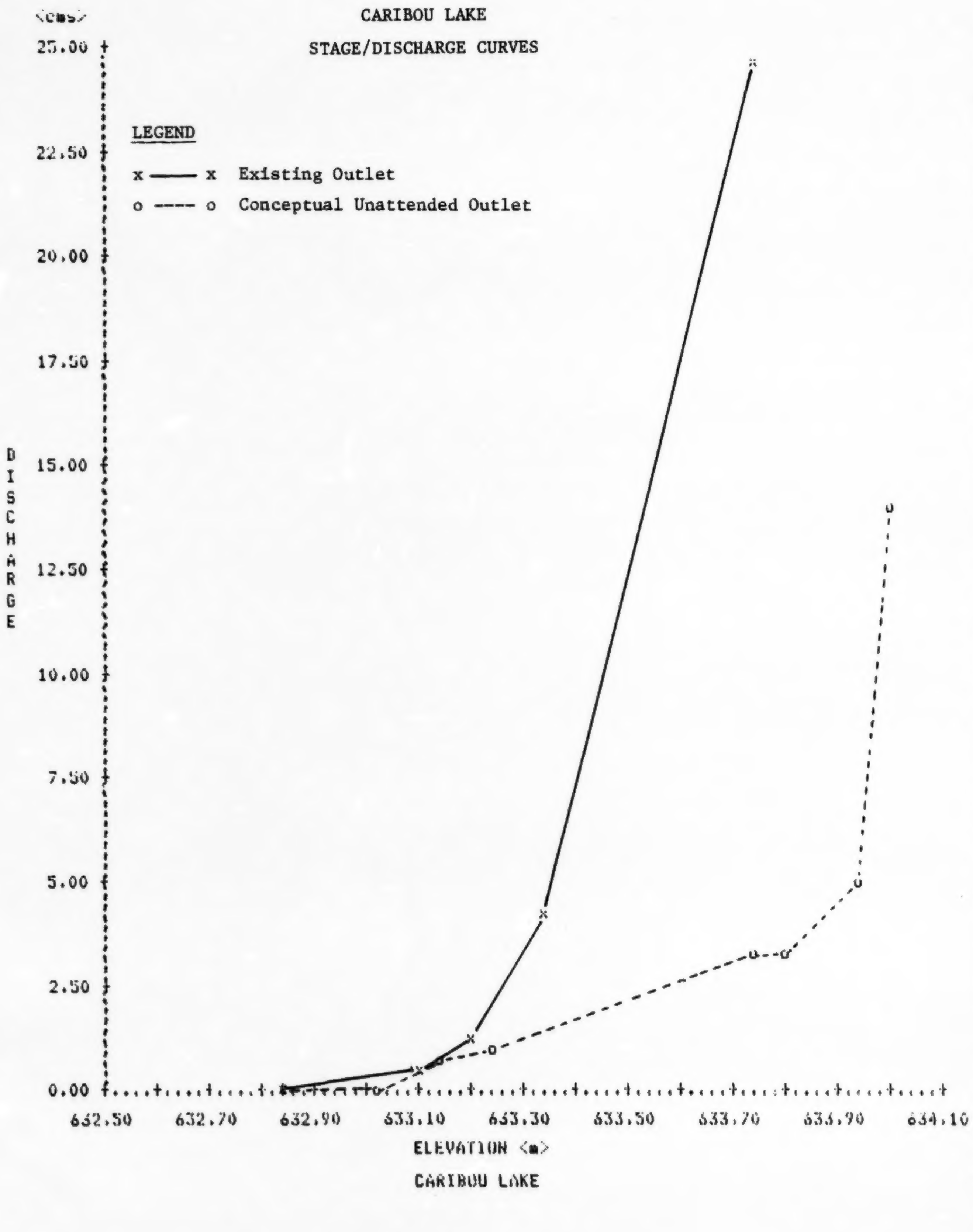


<cms>
COLD LAKE
STAGE/DISCHARGE CURVES
LEGEND
x —— x Existing Outlet
o ---- o Conceptual Unattended Outlet
DISCHARGE
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
533.00
533.50
534.00
534.50
535.00
535.50
536.00
536.50
537.00
ELEVATION <m>

COLD LAKE

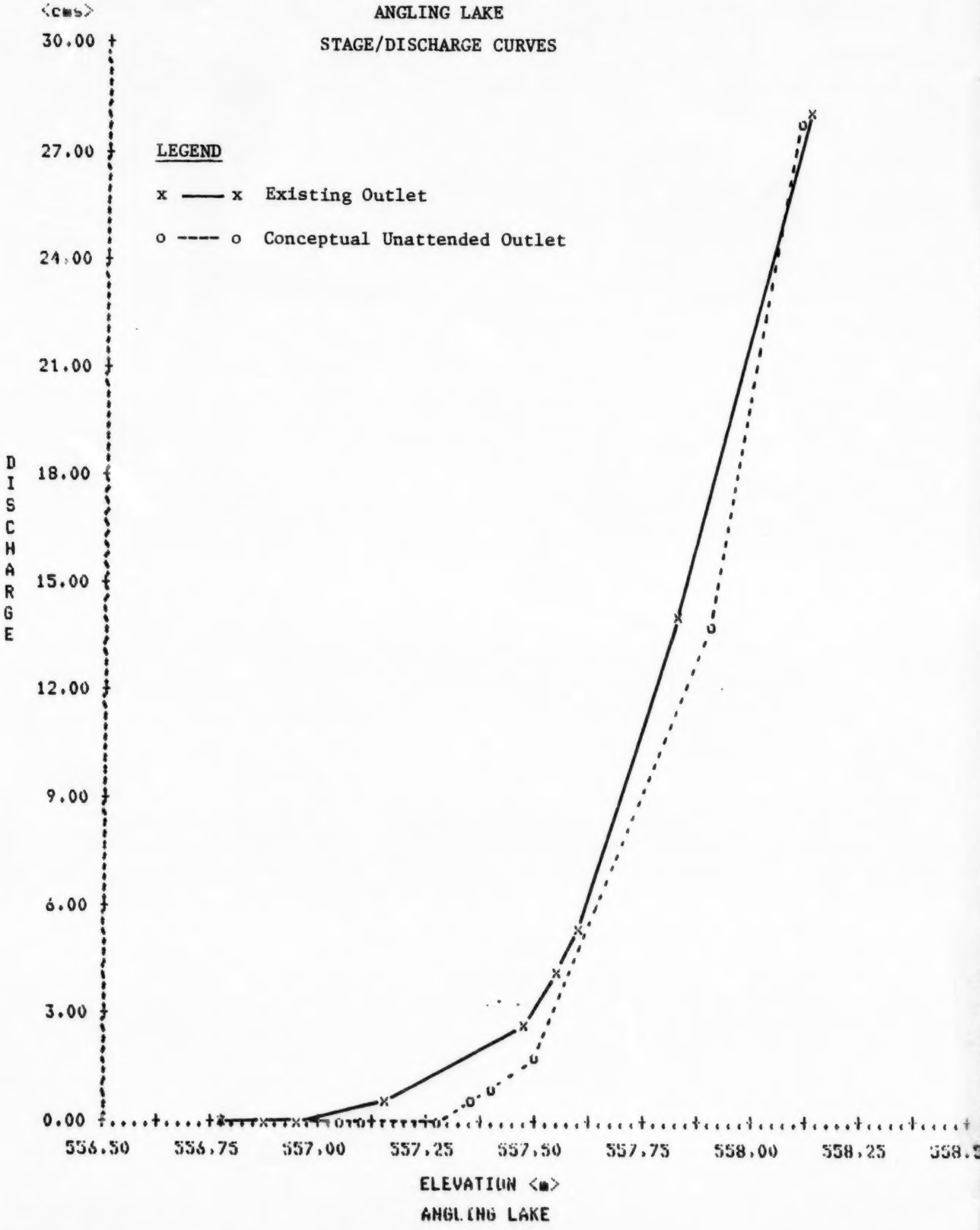

<cms>
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
DISCHARGE
MOOSE LAKE
STAGE/DISCHARGE CURVES
LEGEND
x —— x Existing Outlet
o ---- o Conceptual Unattended Outlet
532.70
532.80
532.90
533.00
533.10
533.20
533.30
533.40
533.5
ELEVATION <m>

MOOSE LAKE



CARIBOU LAKE

STAGE/DISCHARGE CURVES



<cms>
ANGLING LAKE
STAGE/DISCHARGE CURVES
LEGEND
x —— x Existing Outlet
o ---- o Conceptual Unattended Outlet
DISCHARGE
30.00
27.00
24.00
21.00
18.00
15.00
12.00
9.00
6.00
3.00
0.00
556.50
556.75
557.00
557.25
557.50
557.75
558.00
558.25
ELEVATION <m>
ANGLING LAKE

MAPS NOT

FILMED

CARTES

OMISES

POOR

QUALITY

ORIGINAL